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FROM THE DEPARTMENTS OF ORTHOPAEDICS AND ANATOMY, UNIVERSITY OF GOTHENBURG AND THE BIOMECHANICS LABORATORY AND THE DEPARTMENT OF ANATOMY, UNIVERSITY OF CALIFORNIA SCHOOL OF MEDICINE

THE ANATOMICAL BASIS FOR LOW BACK PAIN

Studies on the presence of sensory nerve endings in ligamentous capsular and intervertebral disc structures in the human lumbar spine

By

CARL HIRSCH, BO ERIC INGELMARK and MALCOLME MILLER

Clinical Introduction

In spite of numerous clinical and patho anatomical studies during the past there are still different opinions concerning the interpretation of low back pain. The site of the underlying pathology has been focused on two areas, the discs and the vertebral joints. Degenerative changes in the lumbar discs have in many centres evidently been accepted as the main source of low back pain as ruptures in the posterior part of the annulus are often the cause of sciatica.

Sensory nerve endings have hitherto not been found elsewhere in discs than in the long back ligaments and at the site of junction of the posterior longitudinal ligament with the annulus fibrosus (*Hovelaque* 1925, *Jung & Brunschwig* 1932, *Tsukada* 1938, *Roofe* 1940, *Ehrenhaft* 1943, *Wiberg* 1949). Low back pain was therefore explained as a disorder where the posterior longitudinal ligament was mechanically affected.

Attempts to measure the amount of deformation at the outer borders of normal and degenerative interspaces proved that differences in deformation between normal and pathological discs were very small (*Hirsch* 1954, 1956). When, however, the intradiscal pressure was increased by injection of normal saline or contrast material for radiographic purposes, low back pain of clinical identity could be reproduced (*Lindblom* 1948, *Hirsch* 1948). The intradiscal pressure has been studied by *Nachemson* 1960. Normally the nucleus follows hydrodynamic laws. In degenerated discs the pressure distribution varies. Measurements and mechanical analyzes illustrated that the annulus could be subjected to considerable stress.

When degenerated discs were studied histologically, it was often noted that great numbers of blood vessels had grown between the ruptured and deteriorated collagenous annulus bundles (*Hirsch & Schajowicz* 1952). The areas where granulation tissue could be found were thought likely sites of sensory nerve terminations. However, nerve endings have not as yet been observed in this location.

While it has been easy to find evidence of pathology in discs but difficult to illustrate sensory nerve endings to explain the symptomatology, the reverse is true of the vertebral joints. *Ghormley* in 1933 coined the facet syndrome, to which *Badgley* 1941 concluded: "The anatomical possibilities for the articular facets to play a more or less active part in the production of low back pain are obvious, but pathological evidence is not yet sufficient to make this statement a fact."

Pedersen, Blunck & Gardner 1956 determined the distribution of the lumbosacral posterior rami and the sinu-vertebral branches of spinal nerves. The posterior rami, in addition to their cutaneous and muscular distribution, give sensory fibers to fascia, ligaments, periosteum and intervertebral joints. Adjacent divisions overlap in their area of supply. Interspinous ligaments are supplied mainly by branches from the next cranial level. Sinu-vertebral nerves supply posterior longitudinal ligament, dura mater, periosteum and blood vessels, show intersegmental anastomoses and contain sensory fibers.

The pattern of low back pain is complex. A variety of symptoms present different types of clinical pictures even in the same patient over a period of time. It is possible that the disc pathology may affect the function of joints and ligaments in interfering with a functional anatomical unit or that we have to accept more than one localization of the pathology. It has been suggested that clinically a painful stimulus to any deep structure in this region is poorly localized and can give rise to a common symptom complex (*Pedersen, Blunch & Gardner* 1956).

It is, however, felt that studies on the pattern of sensory nerve endings and their modalities in the different structual elements in the lumbar spine may offer further neuro-anatomical explaination for lumbago.

The anatomy of the lumbar spine

The basic anatomical and functional unit of the vertebral column is the articular triad consisting of the fibrous intervertebral joint and the two synovial vertebral joints. This articular triad is stabilized at

the joints of the extremities by a ligamentous apparatus and permits movements in the spine by the action of a complex coordination of muscle function and gravity

The details of the fibrous intervertebral joint have long been well known and the synovial intervertebral joints have recently been restudied by *Lewin, Moffett & Vudik* 1961

The fibrous intervertebral joint is formed by two adjacent vertebral bodies and the intervertebral disc The disc consists of the annulus fibrosus and the nucleus pulposus The annulus shows a complex system of fibers forming lamellae or bundles Part of the outer lamellae which run parallel to the long ligaments is connected by means of a preparatory calcified zone with the marginal bone edge of the vertebral body *Erdheim* 1931 The inner and the largest part of the annulus fibers run obliquely into the cartilaginous plate of the vertebral body and become attached to the subchondral bony layer The nucleus pulposus which consists of a three dimensional network of collagen fibrils enmeshed in a mucoprotein gel is situated in a cavity in the centre of the annulus fibrosus

In the lumbar synovial vertebral joints the superior articular processes are in contact with the inferior articular processes of the superior vertebra The superior joint facet is faced medially and backwards and is gently concave The inferior one is therefore convex and faced laterally and forwards The joint capsule is attached close to the dorsal and ventral margins of the joint but at the superior and inferior ends there are fatfilled articular recesses Ventrally and dorsally the capsule is reinforced by direct contacts with surrounding ligaments and tendons Where the fatfilled recesses communicate with the joint cavity the adipose tissue terminates as a synovial fat pad The adipose tissue of the superior recess is continuous with that around the spinal nerve in the intervertebral foramen The adipose tissue deep to the multifidus muscle extends into the inferior recess of the joint The multifidus muscle covers the lumbar vertebral synovial joints on all sides except ventrally where the joints are in direct contact with the ligamenta flava

The ligaments of the vertebral bodies are the ventral and dorsal longitudinal ligaments According to *Beadle* 1931 and *Hirsch & Schajowicz* 1952 the ventral ligament consists of dense fibrous connective tissue in close union with the annulus fibrosus while the posterior ligament is thinner and consists only of a series of fanlike bands which are not particularly firmly attached to the disc

The ligaments of the vertebral arches are the interspinous including

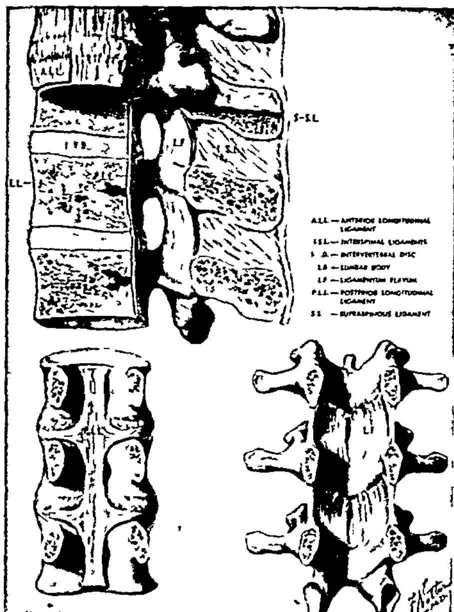


Fig 1
The ligaments of the lumbar spine

the supraspinous group the intertransverse and the ligamenta flava Of these the interspinous ligament is a true ligament

The flavum ligament has the structure and function of a ligament but it also acts as a fibrous capsule on the ventral surface of the lumbar

synovial joint and as an elastic band keeping the spinal nerves free from compression when passing through the intervertebral foramen during movements in the lumbar spine The intertransverse ligaments appear more as a part of the lumbo dorsal fascia than as true ligaments

Besides the multifidus muscle which seems to be a so called articular muscle for the synovial intervertebral joints the muscles of the lumbar region are the sacrospinalis muscles They are attached to the posterior surface of the sacrum and the iliac crest and insert lateral of the angulus of the ribs The multifidus muscle covers the intervertebral joints in its run from the mamillary process to its insertion on a spinous process on a level one to two vertebrae above

The blood vessels of the lumbar spine are branches of the lumbar arteries which run on the lateral aspect of the vertebral bodies and pass close to the intervertebral foramina At this level they give off branches to the structures of the vertebral canal the vertebral arches with their joints and muscles of erector trunci

The nerve supply is to some extent still unknown The vertebral arches and the structure posteriorly to them get their nerves from the dorsal ramus of the spinal nerves This ramus is running in the groove formed by the junction between the transverse and superior articular processes Thus it is first found on the lateral aspect of the superior articular process and then on the medial aspect of the inferior articular process During this course it gives off branches to the intervertebral joints and the erector muscles

The basic articular unit of the vertebral column is as mentioned above the two synovial vertebral joints and the associated fibrous intervertebral joint A movement in anyone of these three joints influences and is influenced by the other two joints in the triad

During flexion and extension of the spine the lumbar articular processes exhibit bilateral sliding movements in the sagittal plane while the nucleus pulposus undergoes displacement either dorsally or ventrally The lumbar vertebral joints appear anatomically designed to facilitate such movements in that their contact surfaces are parallel to the sagittal plane They allow the mobility which is necessary to accommodate displacements of the nucleus pulposus and at the same time lend lateral stability to the spine Lateral bending of the spine occurs by means of similar sliding movements in the vertebral joints On the flexed side each articular process moves into its articular recess

If any rotation occurs at the lumbar synovial joints, it takes place not through an articular mechanism but by means of the slight degree of elasticity which is found in articular tissues.

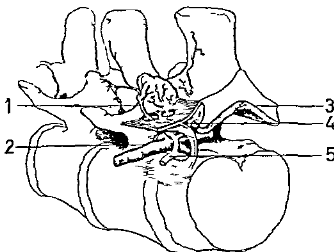


Fig. 2

A drawing showing some of the topographical relationships in the lumbar spine. 1. Dorsal ramus of spinal nerve. 2. Spinal nerve. 3. Lig. flavum. 4. Intertransverse ligament. 5. Lumbar artery.

Methods of studying nerve endings

Nerve endings may be demonstrated histologically by either heavy metal impregnation of formalin fixed tissue or by intravital staining with methylene blue. In anatomical regions such as in ligaments or joint capsules or in other deeply located fibrous structures, nerve terminations are relatively scarce as compared with the more richly innervated cutaneum. The use of methylene blue methods is particularly useful for the study of deep fibrous structures, as large areas of tissue may be stained and studied. Entire joint capsules or broad expanses of ligaments or tendons may be stained either by perfusion or immersion with methylene blue and the nerve endings can be visualized and photographed. Methylene blue has the added advantage of staining very small fibers and with experience one may readily differentiate between nervous and connective tissues.

With heavy metal technics (staining with gold or silver impregnation methods) one is limited to a study of much smaller areas of tissues as sections must be made and it is often very difficult to stain or mark

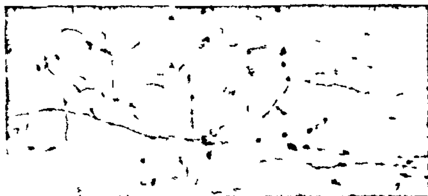


Fig 3
Free fiber endings in the intervertebral joint capsule of a lumbar intervertebral synovial joint × 250



Fig 4
Nerve endings associated with two small groups of fat cells in the interspinous ligament between two lumbar vertebrae × 250

the finer fibers or endings and the problem of connective tissue and nervous tissue differentiation is always present

In our experience we have had very good results with the use of both methylene blue perfusion or immersion technics *Miller* et al 1958 *Miller & Kasahara* 1959 a 1959 b *Ralston* et al 1960 *Miller* et al 1960

We have been able to demonstrate nerve fibers and endings in the ligamentous and joint capsular structures of the lumbar back by use of the methylene blue immersion technic The lumbo-dorsal fascia the supraspinous and interspinous ligaments the ligamenta flava the



Fig 5

Free fiber endings in the outermost layers of the annulus fibrosus just below the posterior longitudinal ligament in the lumbar area × 250

vertebral discs have been obtained fresh from surgery and stained by methylene blue immersion These structures as well as the anterior and posterior longitudinal ligaments and deeper portions of the annuli fibrosi have been studied in relatively fresh cadaver material (four hours post mortem) Because living tissue is required when using the methylene blue technic surgically obtained tissues are more satisfactory than autopsy material

TECHNICAL DATA

Our immersion staining technic consists simply in laying a freshly (usually within one hour after removal from the patient) removed piece of tissue in a 0 005 per cent solution of medical grade methylene blue (may be National Aniline U S P Medicinal C I 922 British Drugs *Methylene Blue B D H* Standard or Chroma Methylenblau med) in physiological saline to a liter of which 8 ml of 0 3 N HCl has been added Staining is carried out at room temperature for 20 or 30 minutes depending on the thickness of the tissue After removal from the staining solution the tissue is rinsed gently in saline and then aired for 5 to 10 minutes on moist gauze or filter paper The tissue is subsequently fixed in chilled (8 C) 8 per cent ammonium molybdate for 6 to 12 hours After fixation the tissues are thoroughly washed in tap or distilled water and then dehydrated in 95 per cent and then absolute alcohol To facilitate microscopy the tissues are flattened between two glass plates held together by paper clips or clamps during the period of de

hydration For relatively thick pieces of tissue such as the interverte bral ligament washing requires approximately two hours and dehydra tion an equal length of time Following thorough dehydration the tis sues are cleared in xylene and then benzyl benzoate The tissues are stored and studied in the latter medium

The sensory nerve endings in human lumbar tissues

As has previously described for many areas of human tissues (see above citations) three types of sensory nerve endings of myeli nated nerve fiber origin are found in most areas of the human orga nism These are 1) endings of small (usually less than 3 μ in diameter) myelinated fibers terminating as single branches 2) complex unencap-sulated endings which are nerve terminations derived from medium sized myelinated fibers (5 to 12 μ in diameter) and varying greatly in form from small Golgi type tendon organs or Ruffini like endings to very large and complexly branched but nevertheless unencapsulated endings and 3) encapsulated endings which vary in form from small Golgi Mazzoni like bulbs to large Pacinian corpuscles

In the fibrous structures associated with the lumbar spine we have seen some of the above type nerve endings in the following anatomical locations

A) Lumbo dorsal fascia
 Fine free fiber and complex unencapsulated endings
B) Supraspinous ligaments
 Fine free fiber and complex unencapsulated endings
C) Interspinous ligaments
 Fine free fiber and complex unencapsulated endings

In almost all anatomical situations the fine terminals of the complex unencapsulated endings terminate intimate association with bundles of collagenous fibers Between collagenous bundles of the interspinous ligaments lie occasional small groups of fat cells The terminations of complex unencapsulated nerve endings have been observed disposed about the walls of the fat cells A similar situation has been described by *Polacek* 1954 in the joint capsule of the hip joint of the rat In our opinion the location of nerve terminals on fat cells implies utilization of the small fatty pads as a mechanical device to register tissue defor mation

In addition to the above types of nerve endings derived from myeli

nated fibers we are able to visualize an unmyelinated nerve fiber network associated with blood vessels While the great majority of the unmyelinated fibers associated with the vasculature are the terminations of post ganglionic sympathetic fibers it is probable that some unmyelinated fibers are autonomic afferent in function From our experience and according to our interpretation we do not recognize an autonomic ground plexus of afferent nerve fibers We have observed what may be the terminals of unmyelinated fibers in deep fibrous structures unassociated with blood vessels but the exact structual relationships and the function of these nervous elements remains undetermined

D) Ligamenta flava

We have seen fine free fiber endings on the outermost layer of the dorsal surface of the ligamenta flava but never in the deeper substance of this structure

E) Anterior and posterior longitudinal ligaments

Both these structures are innervated by fine free fiber and complex unencapsulated endings The posterior longitudinal ligament seems to have a greater number of endings however

F) Annuli fibrosi

Only on the very outermost layers of the annuli fibrosi directly adjacent the under surface of the posterior longitudinal ligament we have found free fiber endings It is probable that these fibers and their endings belong to the same system of nerves supplying the posterior longitudinal ligament Other than in the most superficial layer of the annulus fibrosus we have not found nerve fibers nor their terminations Likewise the nucleus pulposus is devoid of nerve terminals

In a few cases of prolapsed nuclei pulposi we have observed a few fine free fiber endings on the outer surface of the prolapse The latter endings were related to the outermost layers of the annulus or to the adherent posterior longitudinal ligament and had not penetrated the substance of the nucleus pulposus We have not yet had the opportunity of observing whether blood vessels entering a degenerating intervertebral disc provide entry for nerve fibers or nerve endings That such occurs is probable as we observed small myelinated nerve fibers entering opened cartilage spaces in the articular cartilage of arthritic bones In the latter cases the nerve fibers were seen entering the opened cartilage

spaces along with small blood vessels from the trabecular subchondral region

G) The intervertebral joint capsules

These capsules are innervated by the full triad of nerve endings fine free fibers complex unencapsulated and small encapsulated endings In this respect these joint capsules differ in no remarkable manner from any other joint capsule *Ralston* et al 1960 *Stilwell* 1957

H) Vertebral periosteum

Both fine free fiber and complex uncapsulated endings are found in this tissue

I) The lumbar vertebrae

While so far our techniques have not permitted us to visualize the nerves or nerve endings in the trabecular bone of the vertebrae it is highly probable that these structures are well innervated as we have been successful in demonstrating both small myelinated and unmyelinated fibers (not associated with blood vessels) in the subchondral bony trabeculae of the femoral head and condyles in the metatarsal bones and in the navicular and talus bones of the foot (unpublished) Further *Stilwell* 1957 has demonstrated that nerve bundles enter the many vascular foramina in the lumbar vertebrae of monkeys

It is significant that our findings of the nature and distribution of the nerve endings in the ligamentous structures of the human lumbar spine are in close agreement with the findings of *Stilwell* 1957 in the monkey

In addition to the endings of myelinated fibers described above we have found unmyelinated fibers and endings associated both with blood vessels and among the connective tissue fibers (not close to blood vessels) of all the ligamentous structures of the lumbar spine

Clinical interpreparation

The presence of many cartilaginous and ligamentous connections between vertebrae illustrate a complex functional unit In all these elements sensory nerve endings of various types have been found It is however imperative to point out that there is no correlation between structure and function of these sensory elements We merely assume

that unmyelinated free fiber endings may be associated with pain or thermal perception complex unencapsulated endings with tissue position or joint sense and encapsulated endings with pressure perception Besides the possibility that some types of nerve endings may be specialized to respond more readily to certain types of stimuli there is evidence that sensory perceptions may be the result of different types of nerve endings and fibers functioning together and/or certain types of nerve endings may be concerned in the perception of more than one sensory modality

In analyzing the clinical picture of lumbago it is well recognized that it consists of a variety of symptoms including changes in posture These symptoms might be explained by different types of sensory nerve reactions

Since all cartilaginous and ligamentous tissues have sensory nerve endings theoretically pathology affecting any of these elements might cause clinical symptoms If the observations of differences in modality are accepted it would mean that the disc and its longitudinal ligaments would respond with pain only while the joint capsules and ligaments would add loss of joint sense and posture control It is also possible that disturbances at one place could interfere with the function of sensory reactions in other areas resulting in a greater variety of symptoms

Since on the other side very little is known about the function of the sensory endings in these structures one cannot accept this theory unless studies have been made on how the patient responds when the disc the joints and ligaments are subjected to irritation

This subject was touched upon by *Kellgren* 1938 1939 and by *Lewis & Kellgren* 1939 They injected 6 per cent saline into interspinous ligaments and other deep structures and studied the distribution of pain The importance of lesions in posterior intervertebral ligaments as a cause of low back pain was claimed by *Kellgren* in 1942 *Lewis & Kellgren*'s assumption was doubted by *Sinclair* et al in 1948 Their injection of hypertonic saline into interspinous ligaments did not cause referred pain

Studies on pain following injections of hypertonic saline in discs joints and ligaments in the low back

In order to check the different cartilaginous and ligamentous elements as to the symptoms they may cause when subjected to irritation

hypertonic solution of saline (11 per cent) was injected in the following way One thin long needle was introduced between the spinous processes transdurally into the fourth or fifth or both lumbar discs in patients with low back pain Another needle was placed on one of the lower intervertebral joints Positions were checked by X ray in AP and lateral views The patients were in a prone position and were not under any anaesthesia Less than 0 3 ml was injected to the vertebral joint Pain occurred after a few seconds and was very annoying The patients could locate the pain to a distinct area It had some similarity with a low back attack After a while the pain was distributed along the sacro iliac and gluteal areas and then spread out to the greater trochanter It disappeared after a few minutes 0 3 ml was then injected into the disc After a few seconds a very severe pain occurred identical to a real lumbago The patients could not locate the site They felt a deep aching across the low back Under X ray control the needle in the mid line was withdrawn to the level of the flavum ligament A new injection of the same amount of saline gave a very moderate reaction The patients told us that they could spot some pain in the midline of the back When the same manoeuvre was repeated with the needle in the inter spinous and supraspinous ligaments a slightly more pronounced reaction appeared The patients were able to say where the pain came from In the dorsal fascia the reaction was stronger but was still felt as a local affair

These experiments seem to support the conclusion that the disc is the most sensitive area for low back pain The vertebral joints may come into consideration Posterior ligamentous structures do not give clinical evidence of lumbago

SUMMARY

The presence and pattern of sensory nerve endings have been studied in discs joints and ligaments in the lumbar spine In tissues removed at surgery and from fresh autopsies sensory nerve terminals have been demonstrated by intravital staining with methylene blue

Fine free fibers and complex unencapsulated endings have been found in the lumbo dorsal fascia supra and interspinous ligaments vertebral periosteum and anterior and posterior longitudinal ligaments

The intervertebral joint capsules are like other joints and innervated by the full triad of nerve endings fine free fibers complex unencapsulated and small encapsulated endings

In ligamenta flava fine free fibers have been seen on the outermost layer of the dorsal surface but never in the deeper structure

Only in the very outermost layers of the annuli fibrosi directly adjacent to the posterior longitudinal ligament have we found free fiber endings The nucleus pulposes is without nerve terminals

Although very little is established between structure and function of these sensory elements it is assumed that free fiber endings will be associated with pain complex unencapsulated endings with tissue position and joint sense and encapsulated elements with pressure perception

Hypertonic saline injection into ligamentous capsular and disc structures in clinical cases have supported the histological findings of pain fibers and even illustrated differences in response A full low back pain syndrome appeared from the annulus fibrosus some similarity was obtained from the intervertebral joints while the posterior ligamentous structures only caused very localized pain

The pattern of the sensory nerve supply of the lumbar spine widens the basis for analyzing the various components in different types of low back pain syndromes

RESUME

On a etudie la presence et la distribution des arborisations terminales des nerfs sensitifs dans les disques les articulations et les ligaments de la colonne lombaire Dans des tissues preleves au cours d operations ou d autopsies fraiches on a etabli la presence d arborisation terminale de nerfs sensitifs par coloration intravitale au bleu de methylene

Des filets libres et des arborisations terminales sans gaine ont éte trouves dans le fascia lombo dorsal les ligaments supra et interepineux le perioste vertebral et les ligaments longitudinaux anterieur et posté rieur

Les capsules des articulations intervertebrales sont comme celles des autres articulations elles sont innervees par toute la serie d arborisations terminales de filets libres d extremites sans gaine et enveloppees de gaine

On a egalement observe des filets libres dans la couche exterieure de la surface dorsale des ligaments jaunes mais jamais dans les structures plus profondes

C est seulement dans les couches superficielles de l anneau fibreux directement adjacentes au ligament longitudinal posterieur que nous

avons trouve des bouts de filets libres Le noyau pulpeux n a aucune arborisation terminale de nerf

Bien que l on n ait pas des connaissances etendues sur les rapports entre la structure et la fonction de ces elements sensitifs on suppose qu il faut associer le bout des filets libres a la sensation de la douleur l arborisation terminale sans gaine a la sensation de la position des membres et l element enveloppe de gaine a la sensation de la pression

Des injections salines hypertoniques effectuees en clinique dans les ligaments les structures capsulaires et discales ont appuye les trouvail les histologiques de ces fibres douloureuses et elles ont illustre aussi la difference des reactions Un syndrome prononce de douleur dans la partie inferieure du dos partait de l anneau fibreux Quelque chose de similaire a ete observe par rapport aux articulations intervertebrales alors que les structures du ligament posterieur ne provoquent que des douleurs fortement localisées

La distribution des nerfs sensitifs dans la colonne vertebrale elargit la base de l analyse des elements varies que constituent les differents types de syndromes douloureux dans la partie inferieure du dos

ZUSAMMENFASSUNG

Das Vorhandensein und die Verteilung von sensiblen Nerven in Zwischenwirbelscheiben Gelenken und Ligamenten in der Lendenwir belsaule wurden untersucht In Geweben die anlässlich chirurgischer Eingriffe entfernt worden waren und an frischem autoptischen Mate riale wurden sensible Nervenendigungen mittels intravitaler Färbung mit Methylenblau nachgewiesen

Feine freie Fasern und komplexe nicht eingekapselte Endungen wurden in der lumbo dorsalen Fascie den ligamenta supra und inter spinosa dem Wirbelperiost und den ligamento anteriora und posteriora gefunden

Die intervertebrale Gelenke werden wie andere Gelenke durch die *dreifache Art von Nervenendigungen versorgt nämlich* von freien Fa sern komplexen nicht eingekapselten und kleinen eingekapselten Ner venendigungen

In den ligamenta flava wurden feine freie Fasern in der aussersten Schichte der dorsalen Oberfläche aber niemals in den tieferen Lagen gesehen

Nur in den aussersten Lagen der annuli fibrosi die dem ligamentum

longitudinale posterius direkt anliegen haben wir freie Fasern gefunden Der nucleus polposus hat keine Nervenendigungen

Obwohl sehr wenig uber den Zusammenhang von Struktur und Funktione dieser sensiblen Element bekannt ist nimmt man doch an dass freie Faserendigungen mit dem Schmerz komplexe nicht eingekapselte Endigungen mit Gewebsposition und Gelenksgefühl und eingekapselte Elemente mit Druckgefuhl in Zusammenhang stehen

Injektion von hypertonischer Kochsalzlosung in Bander Gelenkskapseln und Zwischenscheiben in klinischen Fällen haben die histologischen Befunde von Schmerzfasern unterstutzt und sogar Verschiedenheiten in der Reaktion aufgezeigt Ein volles Lumbagosyndrom wurde vom annulus fibrosus ausgelost ähnliche Symptome wurden von den intervertebralen Gelenken erhalten wahrend in den posterioren Bandstrukturen nur sehr ortbundener Schmerz hervorgerufen werden konnte

Die Anordnung der sensiblen Nervenversorgung der Lendenwirbelsaule erweitert die Basis fur die Analyse der verschiedenen Komponenten bei unterschiedlichen Typen des Lumbagosyndromes

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RESULTS OF EARLY OPERATIVE TREATMENT OF SCIATICA

By

SVEN DAHLGREN

Opinions about the indications for operative treatment of sciatica have changed in the last thirty years during which time this treatment has been used. At the beginning the indications were very strict. *Friberg & Hirsch* described the average preoperative duration of the disease as being 4½ years in a series operated between the years 1939–1940 (1946). Since then the indications have been broadened and during the last ten years the opinion has been that operation was indicated if the patient, in spite of 2–3 months conservative treatment with rest and physiotherapy, still had pronounced pain (*O'Connel* 1950, *Söderberg* 1956, *Hirsch* 1957–1958). However, as early as 1947 *Barr* considered that it was possible to operate at an earlier stage. Early operation of prolapsed intervertebral disc was also discussed by *Hirsch* at the same time as he described the primary results of 29 cases operated within two months of the onset of the illness (1957, 1958).

To find out if the results of early operation of a prolapsed disc are as good as those achieved after a longer period of conservative treatment, a follow-up investigation was carried out on 41 cases of prolapsed disc operated in the acute stage. The results of this investigation are described here.

MATERIAL

The series consists of prolapsed discs operated in Falun between the years 1954–1957 and in Uppsala between 1956–1958. The total number of prolapsed discs operated during each period was respectively 360 cases in Falun and 288 in Uppsala. Of these 23 patients in Falun (6.4 per cent) and 18 in Uppsala (6.2 per cent) were operated early with a history of between 1 and 6 weeks since the onset of the illness

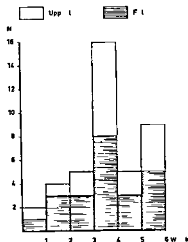


Fig 1
Length of illnes before operation

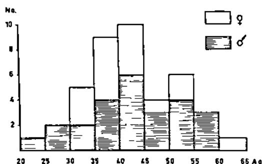


Fig 2
Age and sex distribution of the series

(Fig 1) Of these 41 patients operated early 25 were men (61 per cent) The mean age was 42 years the youngest being 22 and the eldest 66 (Fig 2) The indication for operation had been persistent severe pain combined with pronounced neurological signs in the majority of cases

Myelography was carried out in 7 of the Falun patients and all of the Uppsala patients

PRIMARY RESULTS

In the Uppsala series it was possible to confirm the myelography findings at operation in all cases In five of the Falun patients who

underwent myelography the roentgen film showed a prolapsed disc and at operation it was possible to remove it in four patients In the other two cases the myelogram was negative but at operation a prolapsed disc was found in both cases Prolapsed discs were found in 23 out of 24 (96 per cent) cases following positive myelography The clinical diagnosis with regard to radiation of pain and neurological findings corresponded well with the findings at operation in this series

The immediate results of operation were very good There was rapid relief of pain in those 39 cases where a prolapsed disc was removed at operation One of the two patients where no prolapsed disc was found became rapidly free from symptoms while the other continued to be incapacitated for 14 months In the first case myelography was not performed but in the other case it was carried out and was positive In this case there was certainly a prolapsed disc which the surgeon had missed

The average time of incapacity before operation was two weeks and the average time in hospital 19 days The average time of incapacity after operation was 3 months Of the patients who had their prolapsed discs removed 56 per cent were back at work 2 5 months after operation 79 per cent four months and 97 per cent six months after operation All the patients were able to return to their former work

FOLLOW UP EXAMINATION

A follow up examination was carried out between 1 5 and 5 years after operation One patient had died of another disease Three patients could not be contacted except by letter The remainder were medically examined

The follow up examination in those cases where the prolapsed disc was removed showed that 22 patients (58 per cent) were completely symptom free while 14 (37 per cent) had occasional mild symptoms which however did not interfere with their working capacity The symptoms were localised in part to the leg in eight cases If symptoms of sciatica only are considered 28 patients (74 per cent) were completely free of symptoms while eight (21 per cent) had mild symptoms periodically One patient had symptoms in the back rather often and was not completely satisfied with the result while another had had pain in the other leg requiring hospital treatment

One of the two patients in whom a prolapsed disc was not found at operation only had mild periodic symptoms in the leg The other

patient had had a temporary relapse which was treated conservatively and now he had only mild symptoms in the back

DISCUSSION

The results of the follow up examination of this series of patients operated early for prolapsed discs with 58 per cent completely symptomfree 1.5–5 years after operation is completely comparable with earlier follow up studies of operated prolapsed discs. *Waris* at follow up examination of patients operated for prolapsed disc found that 41 per cent were symptom free (1949) while *Lindgren* in his follow up examination found freedom from symptoms in 58 per cent (1949) and *O Connell* in 60 7 per cent (1950). The present series can also be compared with previous series as regards the frequency of relapse. Lindgren describes a 7 per cent relapse rate, O Connell 2 25 per cent while we in this series had two relapses (5 per cent).

The final results in a conservatively treated series of prolapsed discs does not differ much from results after operation except for the relapse rate which in Soderberg s series amounted to 21 per cent. The difference is greater for the length of hospital treatment and duration of the illness. In Soderberg s conservatively treated series the duration of treatment was 41 days while the duration in the present series was 19 days agreeing with results from elsewhere (*Lindgren* 1949). The average total duration of the disease in the conservatively treated patients in Soderberg s series was 10 4 months while in this series it was 3 5 months. In another series the postoperative time for convalescence following operation for prolapsed disc was 4 months (*Knutsson & Waberg* 1959) and in this series it was three months.

It therefore seems as if the final results following early operation of prolapsed disc are as good as the results of operation after long conservative treatment. Early operation hardly reduces the time of convalescence the only gain being the reduction in the preoperative phase. On the other hand it is well known that conservative treatment can often make operation unnecessary and the question of early operation must therefore be very carefully assessed. It seems advisable to reserve early operation for such cases in which the patient is so ill that conservative measures do not give relief. If early operation is under discussion the diagnosis should preferably be confirmed by myelography (*Hirsch* 1957 1958).

SUMMARY

Forty one patients with sciatica operated within six weeks of the onset have been followed up 1.5–5 years after operation. Fifty eight per cent of the patients became completely symptom free and 37 per cent had only mild symptoms periodically.

The indications for early operation of prolapsed disc are discussed. The gain is that preoperative period is shortened, the postoperative convalescence time is the same regardless of early surgery. It is recommended that early operation be therefore reserved for cases with severe pain where conservative measures do not give improvement.

RÉSUMÉ

Quarante et un malades souffrant de sciatique opérés dans les six semaines qui ont suivi l'attaque ont été reexaminés entre 1½ et 5 ans après l'opération. 58 pour cent des malades avaient été entièrement libérés des symptomes et 37 pour cent de légers symptomes périodiquement.

Il est discuté de l'opération précoce dans les cas de hernie discale. On y gagne parce que la période pré-opératoire est moins longue, mais la durée de la convalescence est la même malgré l'opération précoce. C'est pourquoi il est recommandé de réserver l'opération aux cas où les douleurs sont violentes et où un traitement conservateur n'a apporté aucune amélioration.

ZUSAMMENFASSUNG

Einundvierzig Patienten mit Ischias, die innerhalb von sechs Wochen nach dem Beginn der Symptome operiert worden waren, sind 1.5–5 Jahre nach der Operation untersucht worden. 58 Prozent der Patienten wurden komplett symptomfrei und 37 Prozent hatten nur gelegentlich leichte Symptome.

Die Anzeigen für die frühzeitige Operation der prolabierten Wirbelzwischenscheibe werden besprochen. Die Abkürzung der präoperativen Periode ist ein Gewinn und die Zeit der postoperativen Rekonvaleszens ist die gleiche bei frühzeitigem Eingriff. Man empfiehlt daher die Frühoperation für Fälle mit schweren Schmerzen zu reservieren, in denen konservative Massnahmen keine Besserung ergeben.

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(FROM THE NATIONAL MEDICAL CENTER IN KOREA, DEPT. OF ORTHOP. SURGERY, HEAD OF DEPARTMENT: BERNHARD C. PALS)

OSTEOID OSTEOMA OF THE SPINE

By

BERNHARD C. PALS and TAK KI KIM

Osteoid osteoma was diagnosed in 2.5 % of all tumors of bone and in 9 % of all benign tumors of bone in *Dahlin's* (1) 2,276 cases. He states that *9 % probably is a too low figure.*

There is a general agreement that more than 50 % are localised to the femur or tibia. The localisation to the spine is reported with varying frequency.

Sherman (11) own cases	7 out of 30	(i.e. 1:4)
Sherman (11) literature	11 out of 120	(i.e. 1:11)
Jaffe & Lichenstein (8)	3 out of 33	(i.e. 1:11)
Mustard & Duval (10)	25 out of 280	(i.e. 1:11)
Freiberger et al. (4) literature	33 out of 425	(i.e. 1:13)
Dockerty et al. (2)	1 out of 20	(i.e. 1:20)
Freiberger et al. (4) own cases	3 out of 80	(i.e. 1:27)
Dahlin (1)	1 out of 57	(i.e. 1:57)

Sherman mentions that she probably has a too high proportion because her figures originate from a hospital especially interested in this lesion. *Dahlin* feels that his figure is too low. It may be correct to say that approximately 10 % of osteoid osteomas are localised to the spine.

Usually the site is in the lamina, the facets or the processes, but not in the vertebral body.

The following case may be of interest because of the infrequency of this location. In addition sex and age and history are typical. It is a history of pain. The other symptoms can be explained by this pain: lack of appetite, loss of sleep, incapacity to work, weakness and atrophy of right lower extremity (due to disuse). Typical is a scoliosis with its convexity to the healthy side, while I have not seen reported an increase of the lumbar lordosis. Very typically all symptoms disappeared

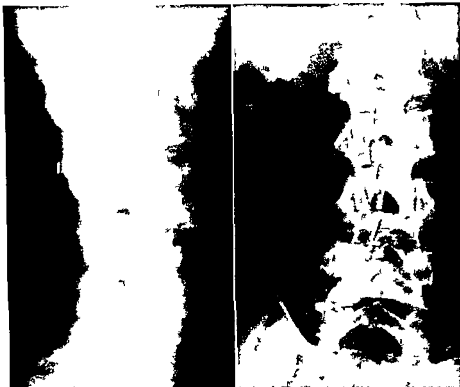


Fig 1

Increased lumbar l rdo is Lumbar scoliosi with co nvex ty toward the unaffected left side Sclerosis in the body of fourth lumbar vertebra right half In the lateral view there is an area of rarefaction in the sclerotic area The discs have normal height The ps as shadow can not be defined

in the course of some weeks after operation The restitution goes so far as to the filling in of the defect on X ray with disappearance of the sclerotic halo

CASE REPORT

The patient wa a 21 year ld man He had pleuris in 1934 At the same time he began to have l a k pain whi h gra luall g t w r e When he was first seen June 19) the pain had made him unable t work f r several months and he was able to be up and ab ut nly part f the day The pain made sleep difficult and disturbed his appetite It increased with c ughing sneezing and defecation The pain was localised to his right lumbar region but gra lually radiated d wn to the right buttock an l p steri r ide f right thigh and leg

H c mplained f increasing weakne f the right l wer extremity l ut had no tice l n change in sen ibility



Fig 2

Tomograph June 15th 1959 The area of rarefaction in L 4 is seen as a defect with sharp contours In the defect lie apomorphous calcifications



Fig 3

Tomographs October 5th 1959 The sharply defined defect and its surrounding "halo of sclerotic bone is seen more clearly than before The defect extends from the bottom of L 4 body to the arch Perhaps it even involves the lower border of the arch close to the body

The disc L 4 5 is preserved

On examination we found that he barely managed to walk with the greatest caution keeping the back stiff The lumbar lordosis was markedly increased and he had a lumbar scoliosis with the convexity to the left Forward bending and bending to the left was almost impossible while backward bending and bending to the right as well as rotation was nearly free He was tender over the lower lumbar spine and the back muscles were tight The right lower extremity was slightly weak and atrophic but showed no disturbance of sensibility or reflexes Sedimentation rate 11 mm

X ray showed the increased lumbar lordosis and the scoliosis In the body of L 4 there was a density in the right part with a sharply defined central defect In the

Fig 4

Highly vascularized connective tissue with many cells Trabeculae of osteoid and of osseous tissue D osteoid osteoma



Fig 5

Tomography February 16th 1960 i e 4 months after operation The lordosis is reduced to normal The defect in the body of the fourth lumbar vertebra can still be seen but is not so sharply defined as before The sclerosis has disappeared No calcifications can be seen in the defect

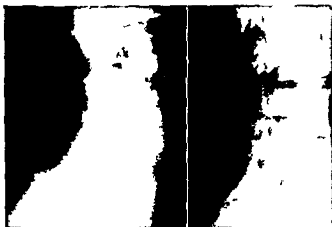


Fig 6

Preoperative and 7½ months postoperative examination Note the difference of lordosis The defect has disappeared even on tomographs (not reproduced)

middle of the defect could be seen an irregular calcification which was interpreted as a sequestrum

A diagnosis was made of probable tuberculosis and the patient got isoniazid 0,3 gram and PAS 8 gram per day while waiting for admission

Four months later he was admitted His condition was unchanged except that his pain was still more severe

At operation the body of L 4 was exposed through a rightsided kidney incision There was no psoas abscess We had to chisel a window through grossly normal looking bone to get to the defect seen on X ray The defect contained a white dense elastic tissue resembling intervertebral disc We found no pus no caseous material no granulation tissue and no sequestrum The defect was curetted completely

Histological examination showed the typical picture of osteoid osteoma while culture of the tissue showed no growth of bacilli

One month after operation the pain had disappeared and he returned to full time work after 3 months working as a painter At six months control the increased lumbar lordosis the scoliosis the stiffness of the back the tendernes of the lumbar spine and the tightness of the back muscles all had disappeared Sedimentation rate ? mm

X ray four months after operation showed the sclerosis to have disappeared and *the defect in L 4 to be reduced in size X ray 7½ months after operation showed no* defect any more

At control 14 months after operation the patient was clinically free of symptoms

SUMMARY

The literature gives the impression that approximately 10 % of all osteoid osteomas are located to the spine Usually the site is the lamina facets or processes A case is reported which was located to the body of L 4

RESUME

De l etude de la litterature il ressort qu environ 10 % de tous les ostéomes osteoides sont localises dans la colonne vertebrale Ordinairement ils siegent dans la lame les facettes ou les apophyses Un cas de localisation dans le corps de la 4eme vertebre lombaire est rapporte

ZUSAMMENFASSUNG

Aus der Litteratur erhält man den Eindruck dass ungefahr 10 % aller osteoiden Osteomata in der Wirbelsaule lokalisiert sind Gewohnlich sitzen sie in den Bogen Facetten oder Fortsatzen Über einen Fall wird berichtet der eine Lokalisation im Korper des 4 Lenden wirbels aufwies

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ELBOW FLEXOR PLASTY IN TENDON TRANSPOSITION

(An analysis of the functional result in 26 patients)

By

KAARE NYHOLM

In the years following the great polio epidemic in Denmark in 1952 an increasing number of patients were referred for orthopaedic reconstruction of their paralytic extremeties

The two main groups of operations applied were arthrodeses and tendon muscle transpositions Frequently a combination of procedures was preferred since efforts were concentrated on achieving the optimal result with regard to both strength stability and coordination

Amongst the aim of reconstructive treatment of upper extremity paralysis was the restoration of active elbow flexion in case of permanent paralysis of the normal elbow flexors (biceps brachii long and short head brachialis and brachioradialis) To fulfill this task Steindler s elbow flexor plasty (1) was favoured whereas the pectoral plasty described by Clare was employed only in a few selected cases

In 1918 Steindler published the results of his first attempts with his new technique Steindler s brilliant idea consists of utilising the forearm flexor group as a substitute for the normal elbow flexors by increasing the muscle group s negligeable lever arm on the elbow joint and thus providing the muscles with a reciprocal task in addition to the original function in the wrist joint hand and fingers

Steindler s operative procedure is performed as follows A longitudinal incision is made along the medial aspect of the elbow joint from 5 cms above the joint to the medial epicondyle and from here swinging radially along the radial edge of the pronator teres to about 5 cms distally of the joint The skin and subcutaneous tissue are reflected and the ulnar nerve is isolated and drawn carefully aside The common head of the flexors is then exposed and released subperiosteally from

the epicondyle In order to obtain sufficient length of the transplant the muscle group is dissected bluntly as far as this is permissible bearing in mind the motor nerve branches from the median and ulnar nerves

Finally the transplant is fixed proximally at the medial rim of the humerus which is exposed by dissection along the medial intermuscular septum between the brachialis and triceps The tendon is fixed to the periosteum or through drill holes in the bone with the elbow in flexed position and the forearm in maximal supination

This position is maintained for 3 weeks in circular plaster of Paris After this period the plaster is replaced by a dorsal splint furnished with flexible joint The degree of flexion is gradually diminished and 6 weeks postoperatively exercises is commenced after removal of the splint

A more detailed analysis of the functional result in a larger series did not emerge until Steindler s own report in 1939 on 29 cases (3) In the following 20 years serial publications revealed the great interest for this intervention (*Carrol & Gartland* 1953 (4) *Mayer & Green* 1954 (5 6) *Schoettstaedt Larsen & Bost* 1958 (7) and *Segal Seddon & Brooks* in 1959 (8))

The above authors all agree with the premises a strong forearm flexor group and a good hand function *Mayer & Green* emphasise the importance of strong wrist joint flexors since these require the major power of the muscle group

A hand capable of function is a conditio sine qua non since the operation would otherwise lack all purpose In case of impaired hand function several authors recommend a primary reconstruction of hand function *Steindler & Carroll* however preferred inverse sequence as they point out that the best result of tendon transfer in the hand is achieved if the origin of the muscles is transposed in advance

2 important drawbacks of Steindler s operation are some restriction of supination and elbow extension In case of pronation contracture tenotomy of pronator teres and/or pronator quadratus may be a good solution while a threatening contracture with restriction of active supination has in several cases been overcome by tendon transposition reinforcing the supination

For the latter purpose Steindler perfers a transposition of the flexor carpi ulnaris around the forearm with fixation to the radius while Tubby has described another method in which the pronator teres and

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The following may be mentioned as the most important alternatives to Steindler's operation

1. Clare's transposition of the pectoralis major to the biceps (2)
2. Brooks & Seddon's modification of the above (9)
3. Bunnell's transposition of the sternocleidomastoideus to the biceps using fascia lata transplant for lengthening
4. Carroll's transposition of the triceps to the biceps

In addition various forms of pectoralis plasty have been utilised since *Schultze Berge* in 1917 (12) made use of the muscle for the first time but it was not until Clare's modification in 1946 that this form of elbow activation was generally accepted

A single case in which the pectoralis minor has been used was published by *E Spira* from Israel (13)

In the present study we employed Clare's operation only in individual cases

Personal series

26 patients operated for elbow paralysis at The Orthopaedic Hospital in Copenhagen dept s I II and III in the years 1951–59

22 cases were polioparalysis 3 trafficlesions of the brachialplexus and a single case a sequence of an obstetric lesion

1/3 of the operations were performed on women 2/3 on men including 2 operations on the same patient with bilateral paresis

The operations were performed 2–6 years after the first orthopaedic consultation with the exception of single cases in which individual factors in the patients invalid condition or the treatment became predominant The premises for operation were generous so far as the claim for full strength in the transposed muscles was not absolute whereas the requirement for adequate hand function was decisive In cases of insufficient hand function the Steindler operation was always preceded by hand reconstruction and the result of this was determining the elbowplastics

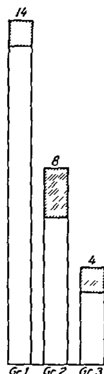
Operative technique

The technical procedure followed the principle stated by Steindler Most frequently the common caput of the flexors was detached from the medial epicondyle by chiseling away a small slice of bone a m Campell in individual cases the tendon was freed subperiosteally

AGE OF DISEASE

Table 1

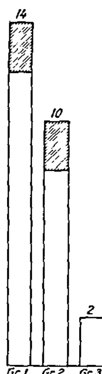
Group		
1	0	9 yrs
2	10	24
3	25	40



PERIOD FROM DISEASE TO OPERATION

Table 2

Group		
1	½	6 yrs
2	7	17
3	23	26



PERIOD FROM OPERATION TO FOLLOW UP

Table 3

Group		
1	2	3 yrs
2	4	6



Patients with plexus lesion

Table 1 The age distribution at the onset of disease or time of lesion ½ of the patients are previous polio children who caught their disease during 0–10 years of age

Table 2 The periods up to the time of operation More than ½ of the patients were operated on within 6 years after the occurrence of paralyses 3 within 2 years

Table 3 The periods from operation to follow up examination More than ¾ of the patients were followed up from 4–6 years postoperatively

Fixation was carried out to the medial border of the humerus from 2–6 cms proximally efforts being made to place the fixation as high as possible with the elbow flexed 90 degrees and with the forearm in maximal supination

In one single patient the tendon was fixed laterally to the anterior aspect of the humerus a m Mayer & Green

The tendons were firmly fixed by drill holes in the bone or to the periosteum and the intermuscular medial septum

After the operation the arm was put into a circular plaster of Paris with the elbow flexed 90 degrees and the forearm in maximal supination 3 weeks later the plaster was changed to a dorsal splint and active excersises of elbow flexion and myotensor treatment were started After another 3 weeks the splint was removed and physiotherapy commenced

Avulsion of the transposed tendon from its bed was not observed in any patient

In 2 patients the classic Steindler operation was supplemented by proximal transposition of muscles from the extensor or radial extensor group One case is differentiated from the others owing to an isolated transposition of the radial extensor group as the flexors were found too weak

RESULTS OF THE FOLLOW UP EXAMINATION

Steindler plastics

Elbow flexion

All patients but one were able to carry out a slow harmonised flexion extension movement of the elbow corresponding to the number of degrees stated (Fig 1) The strength achieved varied from 3–4 while that in 4 out of 5 patients with simultaneous function of the biceps reached at least 4 No one with total paresis of the normal elbow flexors could lift more than 4 pounds

Fig 1

The results of 24 Steindler operations on 23 patients

The middle curves show the elbow flexion—extension in degrees

The arrangement of the curves is determined by an increasing extension deficiency centrally Active supination and pronation can be discovered from the Manchet curves Maximum pronation 0 degrees Maxium supination 180 degrees

The unbroken lines represent movements in patients with fully capable forearm muscles The dotted lines are equal movements in patients with reduced strength in single or several forearm muscles (strength below 4)

Elbow flexion strength is stated according to the following grading

3 flexion to full extent with ¼ pound weight in the hand
3–4 flexion to full extent with [illegible] 2 pound weight in the hand
4 flexion to full extent with [illegible] 4 pound weight in the hand
5 flexion to full extent with normal strength

All patients except 2 preferred to flex the elbow with pronated forearm and clenched hand In the 2 exceptions the forearm was in maximal supination without active pronation

10 were capable of flexing during unchanged supination or semi supination whereas 10 were compelled to pronate during flexion In 4 cases the forearm was in fixed pronation

Of the first mentioned 10 patients 4 had a partially recovered biceps 2 a supplementing extensor transposition and 2 a supination contracture in the forearm Of the last 2 one had some function of brachioradialis and the last one a preoperative function of biceps whereas this function could not be demonstrated at the follow up examination

The preferred position of the forearm and hand is a function of the primary action of the now doubly working muscles and demonstrates the functional basis for the Steindler operation A replacement of the normal flexion supinating mechanism by a flexion pronating mechanism which phylogenetically is probably of an older date

The same phenomenon is demonstrated during flexion tests with the forearm supinated Almost all patients with total paresis of the biceps and brachioradialis and without a supplementing extensor transposition exhibit such a pronation tendency

A shoulder arthrodesis was performed in 6 patients Among the other 18 patients 4 showed fairly slight atrophy and instability in the shoulder while 14 had severely paralysed shoulder girdle with subluxation of the joint during elbow flexion

A study of the preoperative elbow bending capacity showed that 10 patients at that time were able of trick movements in which the elbow could be flexed utilising the shoulder girdle to a position between 90 and 180 degrees Amongst these 3 who were able to flex the elbow above right angle All 3 had initial function of the biceps The others had no active flexion of the elbow

Degree of Elbow Flexion

The evaluation of the degree of elbow flexion is hardly a relevant expression of functional value and shall only serve for the analysis of the varying results

A normal degree of elbow flexion was achieved in but ¼ of the patients All those 6 patients had some type of shoulder stabilisation (arthrodesis (4) and tenodesis (2)) This indicates that stabilisation was of direct value for reaching a maximal degree of flexion

Another characteristic of this group is that it comprises 5 patients

with fully capable forearm muscles and 3 with severe limitation of extension Both factors undoubtedly contribute directly or indirectly to the good flexion result However the other 3 patients in this group did show normal extension to 180 degrees (only one of these with function in biceps) This shows clearly that a fully capable transposed forearm flexor group is able to act sufficiently as elbow flexor through a full range of joint excursion

Elbow Extension

An assessment of elbow extension does not provide such a pessimistic impression as previous authors have assumed

In more than ½ (13) of the patients the extension limitation was less than 10 degrees In 4 between 10 and 25 degrees and in 7 more than 25 degrees In the last group 2 patients stand out with a flexion contracture of 75 and 70 degrees

A direct relationship between the strength of the triceps and the degree of extension can not be demonstrated although a certain connection is indicated

A comparison with the preoperative extension status shows that an increased limitation in consequence of the operation is present in ⅓ of the patients

Supination

According with previous studies the patients are characterised by a limitation of active supination which in a few cases resulted in a pronation contracture

10 out of 24 patients have an active supination equal to or more than 135 degrees including 7 with normal supination 7 an active supination at between 135 and 90 degrees and 5 a supination of below 90 degrees

In 2 patients the forearm had a contracture in supination These 2 patients are characterised by paresis of both pronating and supinating action with reduced strength in the radial part of the flexor group of the forearm (pronator teres and flexor carpi radialis)

A constant finding in all patients was a varying reduction in supination power The pronation power was normal except in 5 patients in whom pareses encroached onto the pronating muscles

Amongst the 7 patients with active supination to 180 degrees 3 had function of biceps and 2 of these showed improved supination in spite of the operation This was owing to the function of biceps

In 20 patients the supination remained unchanged after operation. Only in 4 was found increasing pronation contracture.

Refunction of Biceps

A small number of patients with function in their normal elbow flexors demand special attention since we are confronted here with simultaneous function of 2 flexion mechanisms.

The group consists of 5 patients (Table 4) including 3 with previous traumatic plexus lesion and 2 with polio paresis.

TABLE 4

The results in 5 patients operated according to Steindler and with simultaneous function in biceps

5 patients with refunction of biceps						
Pt	Paresis Etiology	Shoulder arthrodesis	Elbow flex strength	Triceps strength	Elbow flexion	Active supination
I	Plexus	+	4	5	180/70	20 gr (contr.)
II	Polio	+	4–5	3	180/25	180 gr
III	Plexus	—	3	0–1	170/90	90 gr
IV	Polio	+	4	4	105/95 (contr.)	180 gr
V	Plexus	—	4	4–5	175/80	180 gr

Elbow extension was found to be almost normal with the exception of a single patient in whom an excessive extension limitation is probably to be explained by a too severe tightening of the transplant by operation combined with insufficient postoperative extension exercise. The degree of flexion ranges from 90 to 25 degrees probably dependent on the strength achieved by the biceps. In 3 patients there is free supination, in one patient with extensive pareses and numerous tendon transpositions in the hand and the forearm it reaches 90 degrees while in the last of the group a pronation contracture arose preoperatively.

Pectoralis Plastics a.m. Clark

As an alternative to the activation of elbow flexion aided by Steindler's operation pectoralis plastics reported by *Clark* in 1946 was em

ployed in 3 cases For this operation full strength is required in the lower part of the pectoralis muscle

All 3 patients were previous polio children and achieved a normal flexion with only a slight limitation of extension The strength of flexion were 3–4 The result with regard to the 3 factors stated were considerably better than those amongst the patients operated according to Steindler The degree of supination in a single case remained unchanged postoperatively and must be attributed to the complete lack of biceps function Formation of contracture prevented a possible improvement of the supination after operation No anatomical explanation can be given of the obvious and necessary pronation tendency of the forearm in all 3 patients but it may possibly be due to a simultaneous function of the muscles of the forearm where the pronating strength is dominant

DISCUSSION

The growing interest of the last decade in tendon transpositions—their future development and their limitations—could not avoid bringing in those problems which concern the restoration of lost elbow flexion

An adequate discussion of the subject using the present series as a basis requires a comparison with previously published studies of which we have especially chosen *Steindler s* from 1939 *Mayer & Green s* from 1954 and *Segal Seddon & Brooks* from 1959 since these represent patient series of approximately the same size

To a large extent there has been concordance about the indications and premises for operation Concerning the absolute requirement of a strong flexor group however our opinion diverges from that of most authors whose rigorous conditions are determined by the desire of an elbow which can serve as weightbearer or lifter This should undoubtedly be the ideal aim but should not exclude aid to those patients whose muscle status puts such a result out of reach Amongst our patients there is a relatively large number whose forearm muscles are primarily paretic All of these have achieved an elbow flexion of at least 90 degrees which argues quite convincingly in favour of a more liberal attitude when selecting those suitable for operation

There is no divergent opinion about the value of a stable shoulder In our series the importance of an arthrodesis in the shoulder is pointed out both for the total functional result and for the degree of flexion which can itself be obtained The results in cases combined with artho-

desis demonstrate the value of shoulder stabilisation before the Steindler operation

In accordance with earlier surveys we consider a reduced extension as linked with and as a consequence of the Steindler operation The average deficiency in extension is in Carroll s series 40 degrees Seddon & Brook s 60 degrees and Mayer & Green find corresponding values of 30 degrees In our own material it is found to be between 15 and 20 degrees

While most authors point out the importance of this lack of extension which makes the flexion effective by virtue of a flexed initial position Mayer & Green do not find the results satisfactory and accept at the most 15 degrees of limitation of extension

An explanation of the deficient stretching ability has been sought in the relationship between the strength of the antagonistic muscles around the elbow joint In agreement with our own investigations Seddon & Brooks have demonstrated a certain relationship between the strength in the triceps and the degree of extension and at the same time have been able to attribute the most severe limitation to those cases where flexor plastics were supplemented by proximal transposition of the extensor group

In contrast to this we have found 6 cases with accompanying extensor transfer or with refunction of biceps who have achieved almost normal elbow extension These patients all had relatively good triceps strength so that they do not form any decisive argument against the theory about the significance of the antagonistic strength relationship

The slight limitation in extension amongst our patients is rather surprising in view of the poor triceps status and varying function of the biceps The explanation may perhaps be found in the limitation of the transplant strength and the consequently limited effect on the antagonistic strength relationship

It should be noted here that Seddon & Brooks using Carroll s triceps transplantation observed a severe limitation of extension while the use of pectoralis plastics in agreement with our results rarely were followed by a limitation of more than 15 degrees This last point argues that other factors linked with the operative procedure itself determine the degree of extension limitation Here one should point out the fundamental difference between Steindler s and Clark s operation The former operates directly on the anterior aspect of the joint while the latter operation does not touch this important region

The degree of flexion is not the decisive factor in the functional re

sult Steindler demands at least 60 degrees Mayer & Green require free flexion to at least 50 degrees while our patients have all been able to flex to 90 degrees

The most important problem seems to be a flexion to the horizontal position from which further movement will be accompanied by decreasing weight Nevertheless there are numerous of our patients who have obtained a degree of flexion of just below 90 degrees though further active flexion is impossible When considering the slight limitation of extension in these patients and the results from other series with larger extension deficiency and at the same time a greater degree of flexion the problem seems rather to comprise the active span of the new elbow flexor Can this muscle with correct fixation and sufficient training adjust itself to its new task and carry out a maximal elbow flexion (to 30 degrees) from the normal extension position (180 degrees)? In our series this was achieved in only 3 patients

Like Seddon & Brooks who find no change in passive supination after Steindler s operation we were able to demonstrate a direct relationship between the active supination limitation and the loss of the main supinator the biceps a further limitation of supination and increasing formation of contracture in consequence of the operation only occurred in a few cases

A small group of patients in our series was given special attention owing to simultaneous function of the biceps These 5 patients provide a warning against too early operation while the result of the flexor plastics demonstrates the importance of the biceps muscle in maintaining free supination if passive supination is preserved until the biceps function again

Clare s pectoralis plastics was in 3 cases the alternative to Steindler s operation Like Seddon & Brooks we find the extension limiting effect of this operation to be minimal Flexion to a normal extent with good strength was obtained

SUMMARY

27 elbow plastics were followed up and the results were analysed and discussed with special reference to the flexion and extension results of the elbow the stability of the shoulder and the pronation supination movement of the forearm The main emphasis was laid on the 24 Steindler plastics and 5 of these patients with partial recovering of the biceps 3 pectoralis plastics a m Clare were given speciel attention with reference to the influence on functional result

RÉSUMÉ

27 cas de coudes en matière plastique ont été suivis et les résultats ont été analysés en vue d'établir en particulier le degré de flexion et d'extension du coude, la stabilité de l'épaule et les mouvements de pronation et de supination de l'avant-bras. L'intérêt principal s'est porté sur 24 coudes plastiques Steindler, alors que l'on a examiné avec une attention spéciale par rapport à la différence des résultats fonctionnels 5 de ces malades où le biceps a été remis en fonction et 3 avec pectoraux plastiques selon la méthode de Clare.

ZUSAMMENFASSUNG

27 Ellbogenplastiken wurden nachuntersucht und die Ergebnisse wurden unter besonderer Beachtung der Beuge- und Streckfähigkeit des Ellbogens, der Stabilität der Schulter und der Pro- und Supination des Unterarmes analysiert. Das Hauptgewicht wurde auf 24 Steindler-Plastiken gelegt, während fünf dieser Patienten mit Wiederherstellung des Biceps und 3 Pectoralisplastiken nach Clare eine besondere Aufmerksamkeit hinsichtlich des Unterschiedes des funktionellen Ergebnisse gewidmet wurde.

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THE INTRAOSSEUS ARTERIAL PATTERN OF THE CARPAL LUNATE BONE AND ITS RELATION TO AVASCULAR NECROSIS

By

M L H LEE

In 1910 *Kienbock* described an avascular lesion of the carpal lunate bone that had not previously been recognised

Avascular changes in the lunate may or may not also follow dislocation of bone Although it is generally accepted that necrosis is the result of damage to the blood supply of the bone a search of the literature reveals only limited and conflicting evidence about the intraosseus pattern of the blood supply An investigation has therefore been carried out to analyse the intraosseus arterial pattern and to correlate this with the various clinical avascular lesions of the lunate

MATERIAL

The arterial supply of 53 normal lunates has been examined using the technique described by *Trueta & Harrison* (1953) These were from patients between the ages of 11 and 79 years of both sexes In no instances were necrosed or deformed lunates found

METHODS

After flushing the major vessels from distal to proximal with a warm saline solution the limb was injected via the subclavian or brachial artery with 50 % Micropaque suspension in water

After the bone had been stripped of soft tissue it was fixed in 10 % formalin for 4–5 days and then decalcified using 10 % nitric acid

The decalcified bones were examined by X ray and then cleared by the Spalteholz method This made it possible to examine the specimens both by microradiography and by direct vision and for details to be studied under a dissecting microscope

RESULTS

14 (26 %) lunates were found to be supplied from either the palmar non articular surface alone or from the dorsal non articular surface alone by means of a single major vessel often supplemented by one or more minor vessels. 6 bones were supplied from the dorsal surface alone and 8 from the palmar surface. The single vessels enter the medial or lateral border of the appropriate surface of the bone and then traverse the bone in a diagonal direction to end near the opposite border of the other surface of the bone.

Figures 1 and 2 are photographs of a Spalteholz preparation of the injected lunate from the right wrist of a man of 64. Figure 1 shows the specimen from its distal surface and shows the main artery of the bone entering towards the medial border of the palmar surface of the bone and ending near the lateral border of the dorsal surface. Figure 2 shows the same bone photographed from the medial surface. The major vessel is seen to divide into two main branches supplying predominantly the proximal and distal parts of the bone separately.

4 (7.5 %) lunates were supplied by dorsal and palmar vessels that clearly did not anastomose. 2 of these were supplied by a single palmar and a single dorsal vessel, the other two by a single palmar and two dorsal vessels, and a single dorsal and two palmar vessels respectively (Figs. 3, 4 and 5). Figure 3 is of additional interest as it shows pene

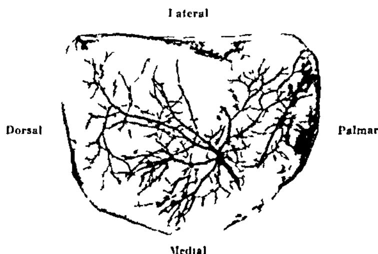


Fig. 1

Male aged 64. Spalteholz preparation viewed from distal aspect showing arterial supply from palmar aspect only.

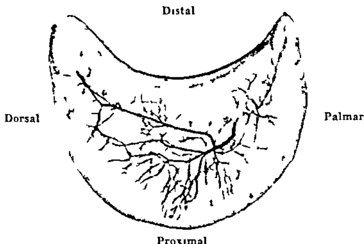


Fig 2

Male aged 64 Spalteholz preparation viewed from lateral aspect

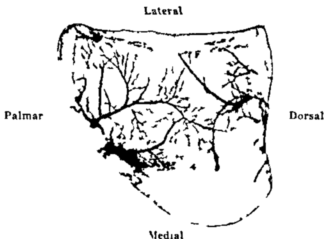


Fig 3

Male aged 11 Spalteholz preparation viewed from distal surface showing double palmar and major single dorsal vessels without anastomosis across the midline Note the vascular sprout penetrating the enchondrium

tration of the enchondrium by a vascular sprout prior to the laying down of bone indicating the association between vascularity and osteogenesis described by *Trueta* (1957)

The remaining 35 (66 5%) lunates were supplied by dorsal and pal

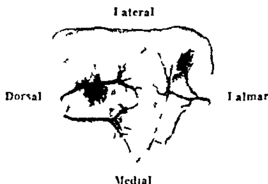


Fig 4

Male aged 11 Radiograph from distal aspect showing double dorsal and single palmar vessels which do not anastomose

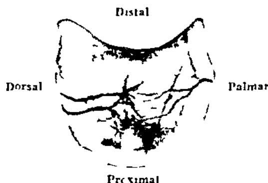


Fig 5

Male aged 11 Radiograph from lateral aspect showing double dorsal and single palmar vessels which do not anastomose

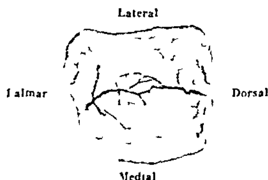


Fig 6

Male aged 18 Radiograph from distal aspect showing single dorsal and palmar vessels anastomosing.

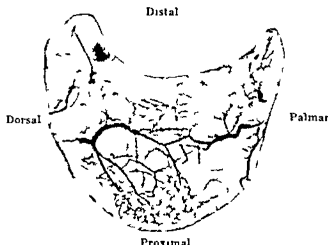


Fig 7

Male aged 18 Spalteholz preparation viewed from lateral aspect showing anastomosis between single palmar and dorsal vessel with branches to proximal part of lunate ending in a subchondral network

mar vessels of varying numbers which anastomosed across the midline of the bone in various patterns as follows

21 (40 %) bones had a main single dorsal and a main single palmar vessel 16 (30 %) with a single central anastomotic channel (Figs 6 and 7) and 5 (10 %) with a ring anastomosis in the centre of the bone from which branches were given off to the rest of the bone (Fig 8)

14 (26 5 %) bones had varying numbers of dorsal and palmar vessels all anastomosing across the midline (Fig 9) the commonest pattern being one dorsal with two palmar vessels which occurred in 5 (10 %) specimens In one specimen only in which the supply was by one pal mar and two dorsal vessels was there a ring anastomosis between the palmar and dorsal vessels (Fig 10)

When there was a simple anastomosis between dorsal and palmar vessels this was usually in the centre of the bone In a few instances it was found to lie distal to the centre of the bone it was never found to lie proximal to the centre of the bone

All 6 (11 %) lunates in which there was a central ring anastomosis between palmar and dorsal vessels also showed a characteristic pattern of distribution This vascular anastomotic ring invariably lay obliquely within the bone so that one half of the ring lay nearer to the distal surface and one half nearer to the proximal surface of the bone (Fig 8)

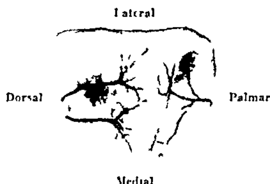


Fig 4
Male aged 11 Radiograph from distal aspect showing double dorsal and single palmar vessels which do not anastomose

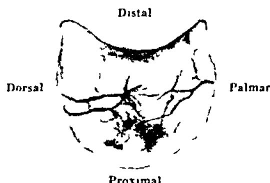


Fig 5
Male aged 11 Radiograph from lateral aspect showing double dorsal and single palmar vessels which do not anastomose

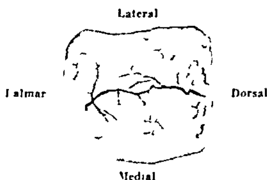


Fig 6
Male aged 18 Radiograph from distal aspect showing single dorsal and palmar vessels anastomosing

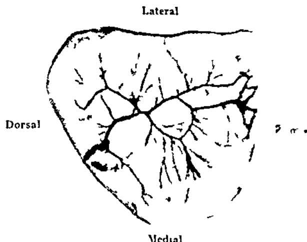


Fig 10
Male aged 5? Spalteholz preparation from distal aspect showing ring with typical "right angle" branches from ring and main vessels

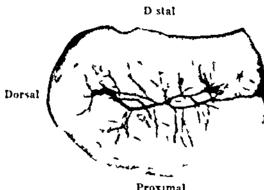


Fig 11
Lunate of Figure 8 viewed from lateral aspect showing horizontal vessels with branches leaving at "right angles"

From each half of the ring major transverse branches to the appropriate proximal or distal half of the bone major part of these portions of the bone

It was found that within the lunate the main artery at regular intervals which often left it at a right angle the surface of the bone (Figs 3 6 7 8 9 10 and 11





Fig. 12 *Fig. 13*

Collapse of the proximal part of the lunate

distance from the main vessel these branches divide obliquely and continue to subdivide until they end in a fine subchondral network (Figs. 6 and 7).

REVIEW OF THE LITERATURE

In a comprehensive study of Kienböck's disease *Ståhl* (1947) discusses the main aetiological theories and offers considerable evidence in favour of the fracture theory. This postulates a primary transverse compression fracture which damages the intraosseus circulation leading to avascular necrosis of the bone. Secondary vertical fractures and resorption and transformation processes within the bone produce the typical X-ray changes.

The theory is supported by *Persson* (1950) who discusses the value of operative lengthening of the ulna as a method of treatment believing that disproportion in length of the radius and ulna is a factor which predisposes to a compression fracture of the lunate.

Mouat, Wilkie & Harding (1932) also considered that the necrosis was the result of damage to the vessels in the lunate by a fracture, though *Durbin's* (1951) opinion based on three cases in which the lunate showed total necrosis was that every case of Kienböck's disease could not be the result of a compression fracture. *Marek* (1957) however suggested that the vessels entering the palmar aspect of the bone were damaged before they entered the bone by a hyperextension injury. In 1938 *Logroscino & de Marchi* described in detail the extra-osseus

origin from the palmar and dorsal arterial complexes of the arteries supplying the lunate They found intraosseus anastomoses between the vessels entering the dorsal and palmar surfaces of the bone as described by *Kostler* in 1936 The supply of the bone by a single palmar or a single dorsal vessel was suggested by *Cordes* (1930) and *Ståhl* (1947) who found the lunate supplied from the palmar surface alone in twenty nine out of thirty injected specimens

DISCUSSION

This investigation indicates that the lunate is supplied via the dorsal and palmar interosseus surfaces alone and that the interosseus vascular pattern falls into one of three groups

Group A A single palmar or dorsal vessel crossing the bone obliquely (26%)

Group B Palmar and dorsal vessels which do not anastomose (7 5%)

Group C Palmar and dorsal vessels which anastomose (66 5%)

From the horizontally running anastomotic channels large branches are given off to the proximal and other surfaces of the bone

It is usual in Kienbock s disease to find the proximal part of the bone necrotic and deformed whilst the distal part is rarely affected (*Kienbock* 1910 *Ståhl* 1947) Figs 12 and 13

This investigation shows that it is impossible for a dorsal or palmar capsular lesion with associated extra-osseus damage to the vessels entering the bone to lead to proximal necrosis of the lunate Damage to the dorsal or palmar capsule alone would lead in group A to either total necrosis of the bone or to no change at all depending on whether or not the vessel supplying the bone lay in the damaged capsule In group B it should theoretically produce palmar or dorsal necrosis alone a lesion which does not appear to have been described In group C it should lead to no necrosis at all owing to the wide anastomosis between dorsal and palmar vessels within the bone

It is easy to see how a transverse compression fracture across the proximal parts of the lunates illustrated in Figs 2 5 7 8 and 11 will deprive the proximal part of the bone of its blood supply leading to the typical proximal necrosis of Kienbock s disease This fracture will cross and interrupt the arterial branches as they run between the anastomotic vessels and the proximal surface of the lunate It is also perfectly rea

sonable for this fracture line to leave intact the anastomotic vessel so preserving the blood supply to the distal part of the bone.

If the transverse compression fracture line lay a little more distally it would interrupt the main vascular anastomotic vessel and produce total necrosis of the lunate. *Ståhl* (1947) found that the compression fracture did indeed cross the bone concentric with the proximal articular surface and at varying distances from this surface.

In traumatic dislocation of the lunate it is usual for the dorsal capsule to rupture and for the lunate to hinge forward on the intact palmar capsule (*Fygers* 1933). Necrosis of the lunate following dislocation is rare (*Russell* 1949). This is as expected when one considers the blood supply of the bone, as it can only occur in the lunates that fall into group A and only in those whose single artery of supply enters the dorsal interosseus surface.

SUMMARY

The intraosseus pattern of the blood supply of the carpal lunate bone has been examined by microradiography and Spalteholz preparations after injection of a Micropaque suspension.

Three main patterns are described:

Group A. A single palmar or a single dorsal vessel crossing the bone obliquely (26 %).

Group B. Supply by palmar and dorsal vessels which do not anastomose within the bone (7.5 %).

Group C. Supply by palmar and dorsal vessels which anastomose within the bone (66.5 %).

The anastomosis lies in the centre or slightly distal to the centre of the bone supplying major branches to the various parts of the bone.

Kienbock's necrosis of the lunate commonly affects the proximal part of the bone alone and can be caused by a proximal horizontal compression fracture crossing the vascular branches to the proximal part of the bone. A more distally placed fracture will interrupt the anastomotic channel or the main vessels within the bone causing necrosis of the whole lunate.

Necrosis of the lunate rarely follows dislocation of the bone. This is apparent when one realises that only those supplied by the group A pattern and whose sole vessel of supply lies in the ruptured dorsal capsule will be affected.

RESUME

Le dessin intraosseux de l alimentation sanguine de l os du carpe lunaire a ete examine par microradiographie et preparations Spalteholz apres injection d une suspension micropaque

Trois dessins principaux sont decrits

Groupe A Un seul vaisseau palmaire et un seul dorsal croisant l os obliquement (26 %)

Groupe B Alimente par vaisseaux palmaires et dorsaux qui ne forment pas anastomose dans l os (7.5 %)

Groupe C Alimente par des vaisseaux palmaires et dorsaux qui forment anastomose dans l os (66.5 %)

L anastomose se trouve au centre ou a une legere distance distale du centre de l os alimentant les branches principales des differentes parties de l os

La necrose Kienbock de l os lunaire touche en general la partie proximale de l os et peut etre causee par une fracture de compression horizontale proximale croisant les branches vasculaires de la partie proximale de l os Une fracture placee plus distalement coupe le canal anastomosique ou les vaisseaux principaux a l interieur de l os causant une necrose de tout l os lunaire

Une necrose de l os lunaire suit rarement une dislocation de l os Cela semble evident lorsqu on realise que ce sont seulement les vaisseaux d alimentation du dessin du groupe A et dont le seul vaisseau d alimentation se trouve dans la capsule dorsale ou il y a rupture qui se trouvent touches

ZUSAMMENFASSUNG

Die intraossare Anordnung der Blutversorgung des os lunatum wurde mittels Mikroradiographie und Spalteholz Präparaten nach Injektion einer Mikropaquesuspension untersucht

Drei Hauptandordnungen werden beschrieben

Gruppe A Ein einzelnes Gefass das den Knochen palmar oder dorsal überquert (26 %)

Gruppe B Versorgung mit palmaren und dorsalen Gefassen die innerhalb des Knochens nicht anastomosieren (7.5 %)

Gruppe C Versorgung mit palmaren und dorsalen Gefässen die innerhalb des Knochens anastomosieren (66.5 %)

Die Anastomose liegt im Zentrum oder ein wenig distal vom Zentrum des Knochens und versorgt die verschiedenen Teile des Knochens mit grösseren Ästen.

Kienböcks Nekrose des os lunatum greift im Allgemeinen nur den proximalen Teil des Knochens an und kann durch eine proximale horizontale Kompressionsfraktur, die die Gefässäste zum proximalen Teil des Knochens überkreutz, hervorgerufen werden. Ein weiter distal gelegener Bruch wird die Anastomosekanäle oder das Hauptgefäss innerhalb des Knochens unterbrechen und eine vollständige Nekrose des os lunatum verursachen.

Lunatumnekrose entsteht selten als eine Folge der Luxation des Knochens. Das ist verständlich, wenn man sich vergegenwärtigt, dass nur jene Knochen die gemäss Gruppe A versorgt sind und deren Versorgung in der geborstenen dorsalen Kapsel liegt, betroffen werden werden.

ACKNOWLEDGEMENT

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TREATMENT OF UNUNITED FRACTURES OF THE CARPAL SCAPHOID BY BENTZON'S OPERATION

By

OLAF AGNER

According to the recent literature on fractures of the scaphoid bone most authors now prefer conservative treatment of recent fractures in plaster cast. The results are somewhat varied, union being obtained in from about 70 % to about 95 % of the cases within 8–12 weeks. These results have been obtained where the treatment is centralized, where interest is devoted to this particular fracture, and where a routine technique of applying the plaster cast is employed. The results must be assumed to be less favourable in departments where fewer cases are treated, so that sufficient experience cannot always be presumed to have been gained.

Thus a certain number of scaphoid fractures do not unite despite treatment—and to these are added primarily untreated cases, either because the patient has not consulted a doctor or because the fracture has been overlooked in the course of the examination. A number of these cases are diagnosed accidentally, or when the patient presents himself with persistent pain, possibly after a second injury years after the occurrence of the fracture.

Numerous methods have been suggested in the treatment of ununited fractures of the carpal scaphoid. "A study of the extensive literature on the subject is not conducive to peace of mind for the surgeon: there are too many alternatives", as stated by *Lyman Smith*, Illinois, in 1956. I shall not try to discuss every single method, but shall merely enumerate them: excision of one or both fragments, excision of the proximal carpal row, insertion of a prosthesis, prolonged immobilization, internal

Read at the meeting of The British Second Hand Club and The Scandinavian Hand Club in Copenhagen, May 17, 1961.

screw fixation drilling of fragments intercarpal or radiocarpal arthrodesis bone grafting radial styloidectomy

To this long list may be added yet another method which is worth considering Bentzon s operation It does not pretend to be the final solution in the treatment of ununited fractures of the carpal scaphoid However as fairly good results have been reported in 3 series followed up for a long time there seems reason to submit the method for discussion

In the event of nun union of scaphoid fractures Bentzon makes a distinction between 3 types (1) Necrosis of a small usually proximal fragment presenting itself on the X ray film with distinct sclerosis (2) absorptive lesions (traumatic cysts) around the fracture line and (3) actual pseudarthrosis usually dividing the bone into two almost equally large parts According to Bentzon a small necrotic fragment should be excised while in cases of traumatic cysts immobilization should be tried An actual pseudarthrosis is the indication for this operation Bertelsen prefers exstirpation when dealing with proximal fragments less than 1/3 of the bone but Bentzon s method in wider fissures through the waist

Many patients with pseudarthrosis of the scaphoid bone have no pain and little limitation of motion Therefore it was Bentzon s idea that in patients with painful pseudarthrosis the condition might be altered to a painless one by an operation interposing a fat fascia flap between the fragments

In 1939 he started using this method in long standing cases of pseudarthrosis at the Aarhus Orthopaedic Hospital Denmark in collaboration with Randlov The procedure is as follows

OPERATION

A fairly large curved incision is made over the anatomical snuff box and the adjoining distal area The incision should be convex in the dorsoulnar direction The skin flap is retracted and from subcutaneous fatty tissue connective tissue and possibly some tendon sheath a fairly large flap is made Its attachment is proximal just above the styloid process of the radius In this type of scaphoid fracture the fracture line is located just distal to the tip of the styloid process At this site the joint capsule is opened and the fracture line exposed If the appearances are not quite clear a probe is inserted and the site is X rayed After debridement the fracture will gape wide and now the fat-connective tissue flap should be interposed and accurately fixed between the fragments To

this end a nylon suture is applied to the tip of the flap and by quite straight needles both ends of the suture are pulled down through the gap and through the skin on the volar aspect of the carpus. At this site the suture is tied over a small gauze tampon thereby pulling the flap right to the bottom of the fracture line. In the course of this manoeuvre it is of course important not pierce the median nerve or the radial artery. *Tying the suture on the volar aspect fixes the flap in the fracture gap* and makes it fit snugly. The fascia and skin are now sutured. The wrist is fixed in a plaster cast in slight dorsal and ulnar flexion. At the end of 2 weeks the plaster and sutures are removed and of course the suture which has fixed the interposed flap. The patient is then encouraged to use and train his hand immediately.

In Bentzon's opinion it is important not to put off the operation too long, and under no circumstances so long that osteoarthritic changes have appeared. The final therapy has to be decided upon if immobilization for 8–10 weeks has failed to give satisfactory union.

Bentzon & Randlov published their preliminary results in 1944 and 1945. In 1954 *Randlov* reported on a series of 20 patients treated by the interposition method and followed up for periods of from 1 to 15 years. Sixteen were "completely all right", working in their usual occupation to a full extent without any complaints. In 4 the results was "good", i.e. they had returned to their former work but suffered pain upon severe exertions. None had poor results.

Percy also in 1954 conducted a follow up study on 15 out of 17 patients treated at the Orthopaedic Clinic of the Karolinska Institutet, Stockholm, during the period 1940–1950. All had strenuous work. The average period elapsing from the accident to the operation was 4 years and from the operation to follow up 2–9 years, average 5 years. The results were: 10 "completely all right", 4 had slight pain and 1 had "improved". All but one had been able to return to their former work after the operation.

In the majority of cases the mobility in the wrist was reduced but this did not bother any of the patients. Moreover the strength of the hand was reduced but this was not of practical importance except in 3 cases. Radiological evidence of mild osteoarthritis in the radiocarpal joint was found in 11 cases.

At the Orthopaedic Hospital, Copenhagen, 25 patients were treated by the Bentzon operation during the years 1951–1958 inclusive. During the same period a total of 245 patients were referred with fracture of the carpal scaphoid.

The operative indication was in all cases painful pseudarthrosis in most cases accompanied by restricted mobility in the wrist and reduced strength Twelve patients were unable to do their jobs while the others were working with difficulty

Two patients had radial styloidectomy at the same time

Two patients were females 23 males At the time of the operation they ranged in age from 15 to 49 years average 27 2 years

Eighteen patients had heavy work the remaining 7 lighter work

Sixteen fractures were left sided 9 right sided

The majority of the fractures were near the middle of the scaphoid bone 1 in the proximal third and one in the distal third

In 19 instances the fracture had not been diagnosed primarily Five of these patients had been X rayed immediately but without the fracture being detected In 6 cases the diagnosis was made immediately but nevertheless one of them was not treated

Twelve had been treated previously by plaster cast from 5 weeks to 9 months This treatment had been instituted immediately after the injury in only 4 cases in whom it had been continued for 4 months 5 months 6 weeks and 8 weeks respectively In the other patients the treatment has not been started until 4 weeks to 10 years after the accident

One year after the injury 1 patient had been treated because of pain with a plaster cast for 6 weeks but unsuccessfully Two years after the injury drilling by the method of Beck was tried and since the fracture still failed to unite the Bentzon operation was carried out 3 years after the accident

For the sake of completeness it must be mentioned that 2 patients had been treated by massage and X ray therapy

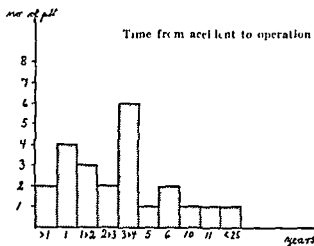
FOLLOW UP

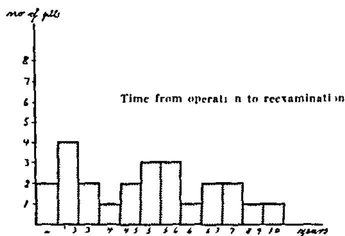
One patient died 6 years after the operation for pseudarthrosis of the scaphoid He was last seen in hospital 7 months after the operation At that time he had been working fulltime as a labourer for 4 months Only heavy impacts would cause mild pain at the site of the scaphoid There was some limitation of the volar less of the dorsal flexion but the mobility was far better than prior to the operation

Twenty four patients were re examined in the period November 1960 to March 1961 after follow up periods of from 2 to 10 years average 5 years (4 years 11 months)

25 patients

23 men — 18 heavy workers
2 women
24 pts followed up
(1pt died 6 years after operation)





At follow up 17 patients *reported that they were fully satisfied with* the result. They could perform any kind of work without pain in the hand. All had returned to their former work.

Four had slight pain after prolonged strenuous work. The pain was of brief duration and never so severe as to induce them to interrupt their work. All four had returned to their former work.

Three still had complaints but stated that the condition was better than before the operation. A boiler maker with pseudarthrosis in the right carpal scaphoid developed pain in the wrist after using the hammer for a long time. Now he was working as a chaffeur and had no complaints. A grocer developed brief pain in the wrist when lifting heavy weights but unlike the previous occasion he could write without discomfort. The third one was a labourer who had been treated previously by immobilization in plaster but not until one year after the accident as the fracture had not been diagnosed. Two years after the accident drilling of the fragments was tried and not until 3 years after the accident did he have a Bentzon operation. He has now been working in his old job for 6 years. He often has to lift heavy weights and this gives rise to pain. During the past few months the condition has become aggravated. At follow up this patient like the one just mentioned was found to have a long styloid process and osteoarthritis in the wrist. One month ago therefore he had radial styloidectomy.

Treatment before operation Immobilisation (plaster cast) 19 cases

primarily			later (the fracture not diagnosed primarily)			
1 pt plaster cast	5	months	1 pt after 5	months	plaster cast 6	months
1 pt plaster cast	4	months	1 pt after 10	years	plaster cast 1½	months
1 pt plaster cast	1 ½	month	1 pt after 1 ½	month	plaster cast 4	months
after ½ year plaster	8	months	1 pt after 1	year	plaster cast 1½	months
1 pt plaster cast		*months*	*1 pt after 1*	*month*	*plaster cast 7*	*months*
after 1 year plaster	4	months	1 pt after 3	years	plaster cast 1½	months
			1 pt after 1	month	plaster cast 4	month
			1 pt after 3	months	plaster cast 1	months

massage 2 cases

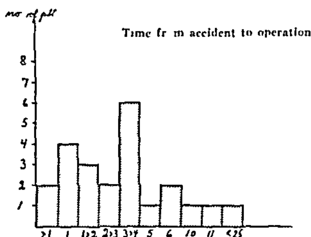
In most of the cases there was some limitation of motion in the wrist. Only a few of the records gave accurate data regarding the mobility prior to the operation but in these cases it was found to be improved. Radial flexion was more often restricted than ulnar flexion and volar flexion more often than dorsal. On the average the limitation of motion was as follows: dorsal 10, volar 15, ulnar 10, radial 15.

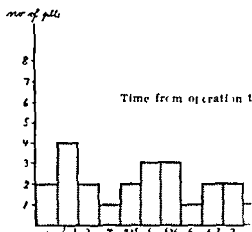
Strength was reduced in 8 cases but this was not of practical importance except in one.

All the 24 patients included in the follow up were X rayed. In 13 this revealed osteoarthritic changes involving the radial part of the wrist and only that part.

25 patients

23 men
2 women
24 ptts followed up
18 heavy workers
(1pt died 6 years after operation)





At follow up 17 patients reported that they w
the result They could perform any kind of wo
hand All had returned to their former work

Four had slight pain after prolonged strenu
of brief duration and never so severe as to in
their work All four had returned to their forme

excellent back in earlier employment no pains no complaints
good back in earlier employment slight pains after heavy work
improved pains and stiffness of the wrist when working but less than before operation
bad unaltered or worse than before operation

results

excellent	17 patients
good	4 patients
improved	3 patients
bad	0 patients
	24 patients

Bentzon's operation is a simple procedure requiring only a short treatment period The patient can soon return to his work As already mentioned the results of this operation have now been reported in 3 series comprising a total of 60 cases followed up for several years after the operation The subjective as well as clinical results are good Osteoarthritis was found by X rays in about half the cases but most of these patients had incipient osteoarthritis before the operation The incidence of osteoarthritis must be a decisive factor in selecting the method of treatment From numerous investigations it is known that osteoarthritis is a common finding in cases with long standing pseudarthrosis in the carpal scaphoid (*Kjeld Andersen & Therkelsen* at the University Hospital in Copenhagen found 36 % but 50 % among operated cases)

In the literature we have not been able to find reports of follow up studies for osteoarthritis in patients treated by other surgical techniques Pending such reports we feel justified in continuing to use the Bentzon operation on the named indications

SUMMARY

At the Orthopaedic Hospital Copenhagen 25 patients were treated according to Bentzon's method for pseudarthrosis of the carpal scaphoid in the years 1951–1958 During the same period 245 patients were referred for fractures of the carpal scaphoid The aim of the operation is to alter a painful pseudarthrosis to a painless one by interposing between the fragments a fat fascia flap from the subcutaneous tissue of the anatomical snuffbox The wrist is fixed in a plaster cast for two weeks after the operation then the patient is encouraged to use and train his hand immediately

24 patients were followed up from 2–10 years after the operation (One patient had died) 17 had excellent results 4 got slight pain after

prolonged strenuous work but never so severe as to induce them to interrupt their work 3 still had complaints but stated that the condition was better than before the operation At follow up all the 24 patients were X rayed —in 13 osteoarthritic changes were seen but in 11 preoperative X rays revealed osteoarthritic changes —in 9 they had progressed In two only no osteoarthritis was seen prior to the operation but slight osteoarthritic changes afterwards

RESUME

A l'Hopital Orthopedique de Copenhague la méthode de Bentzon a été appliquée au traitement de 25 cas de pseudarthroses du scaphoide carpien pendant les années 1951 a 1958 Durant cette meme période 245 malades ont été traités pour des fractures du scaphoide carpien Par l'operation on vise a transformer une pseudarthrose douloureuse en une maladie sans douleur en interposant entre les fragments un bout de fascie gras preleve dans le tissu sous cutané de la tabatière anatomique Le poignet est fixe dans le platre pendant deux semaines apres l'opération puis on recommande au malade d'utiliser et d'entrainer sa main immediatement

24 malades ont ete reexamines entre 2 et 10 ans apres l'operation (*Un malade etait decede*) *Chez 17 les resultats etaient excellents* chez 4 il y avait eu de legeres douleurs a la suite d'un travail pénible prolongé mais les douleurs n'avaient cependant jamais ete assez fortes pour les amener a cesser leur travail 3 continuent a se plaindre tout en reconnaissant que leur etat est meilleur qu'avant l'operation A l'examen tous les 24 malades ont ete passes aux rayons X On a constate des modifications osteoarthritiques chez 13 mais chez 11 la radiographie preoperatoire avait deja revele des modifications ostéoarthritiques — chez 9 malades elles avaient progresse Dans deux cas seulement aucune modification osteoarthritique n'a ete observee avant l'operation mais il y avait de legeres modifications apres l'intervention

ZUSAMMENFASSUNG

Am orthopedischen Krankenhaus in Kopenhagen wurden in den Jahren 1951 1958 25 Patienten nach Bentzons Methode zur Behandlung der Pseudarthrose des os naviculare der Hand operiert Während des gleichen Zeitraumes wurden 245 Patienten mit Bruchen des Kahnbeines der Hand gesehen Man beabsichtigt mittels der Operation eine schmerz

volle Pseudarthrose mittels Einlegung eines gestielten Fett Faszienlappens von dem subkutanen Gewebe der Tabatiere zwischen die Fragmente in eine schmerzlose zu verwandeln Die Hand wird für zwei Wochen nach der Operation im Gipsverband ruhiggestellt und nachher wird der Patient aufgefordert seine Hand ohne weiters zu gebrauchen und zu üben

24 Patienten wurden 2 bis 4 Jahre nach der Operation nachuntersucht (Ein Patient war gestorben) 17 zeigten ein ausgezeichnetes Ergebnis 4 bekamen leichte Schmerzen nach langer anstrengender Arbeit die jedoch u s w unterbrechen mussten 3 Patienten hatten fortgesetzt Schmerzen aber gaben an dass ihr Zustand besser als vor der Operation war Anlässlich der Nachuntersuchung wurden alle Patienten rontgenuntersucht – bei 13 wurden osteoarthritische Veränderungen gesehen aber bei 11 von ihnen zeigten die vor der Operation vorgenommen Rontgenbilder bereits osteoarthritische Veranderungen – die in 9 Fällen zugenommen hatten Nu in zwei Fallen wurde keine Osteoarthritis vor der Operation besehen entwickelte sich aber in leichtem Grade nachher

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FROM THE ORTHOPAEDIC HOSPITAL OF THE INVALID FOUNDATION, HELSINKI
HEAD: A. LANGENSKIÖLD, M.D.

ON THE RESULTS OF TREATMENT OF NON-UNION OF THE SHAFTS OF THE LONG BONES

By

RISTO KIVILAAKSO and MATTI SAARIALHO

The causes of non-union and the methods and results of its treatment have continuously received great attention from orthopaedists as well as general surgeons. The high actuality of the topic is also indicated by the fact that it is still a subject of discussion in various congresses, e.g. at the Congress of the Société Internationale de Chirurgie Orthopédique et de Traumatologie in New York 1960. On this occasion *Boyd, Lipinski & Wiley* presented a series comprising 842 patients, dealing with the results of treatment of non-union of the shafts of the long bones. With advances in surgical technique, non-union should be less frequent, but rather the opposite is true in actual practice. Most of all this is due to the increased number of serious traffic and working accidents which result in open fractures with infection and comminuted fractures with circulatory disturbances.

In Finland the occurrence and treatment of non-union has been little treated in the literature and it is therefore difficult to form an overall picture of the results of treatment in different hospitals. *Rehnberg* (1955) presented the results of treatment relating to non-union in 277 war casualties, and *Biström* (1955) those from the treatment of non-union in 38 cases during peacetime. *Saarialho's* (1960) series of 332 patients with leg fracture contained 24 cases of non-union. For the above-mentioned reasons it is thought to be appropriate to present the results of treatment recorded in the Orthopaedic Hospital of the Invalid Foundation in the years 1945–1960. In his paper, read at a congress, *Nyberg* (1955) dealt with part of the same series, belonging to earlier years. This part, too, was included in our follow-up investigation for the reason that many of the patients have visited our hospital also in recent years for further examination, or the insurance companies have been able to advise us on their recent condition.

The series of non-union cases of our hospital presents a higher than normal degree of severity on the whole because no fresh fractures at all are admitted but the patients are sent to us in the non-union stage from other hospitals when their condition has been considered as requiring special treatment. Thus in a major part of the series one or several operations for the correction of non-union had already been made; this can be considered as having further worsened the conditions for successful recovery.

OWN MATERIAL

The series consists of patients treated in the Orthopaedic Hospital of the Invalid Foundation in the years 1945–1960, all of them with non-union of one of the long bones of the extremities. There are altogether 160 patients, 138 of them male and 22 female.

TABLE 1
Age on Admission for Treatment

Age group	Below 20	20–29	30–39	40–49	50–59	Over 60
Number	11	43	41	38	19	8

The youngest patient was 5½ years, the oldest 67. An overwhelming majority of the patients (altogether 122) were men between 20 and 50 years of age, in their best working years and therefore most susceptible to serious accidents. Each decade of this period is represented by approximately the same number of patients, as can be seen from table 1. The cases of non-union due to lesions received in the war numbered 36, all of them male patients.

Table 2 gives a short review of the patient data prior to admission into our hospital. In specifying the point of fracture, the fractures on the junction between the proximal and middle thirds of the bone have been referred to the group of proximal fractures, and those on the *junction between middle and distal thirds* to the fractures with a location in the middle third. Most of the non-unions in our series occurred in the region of the middle third. An exception is noted in the case of the radius and ulna, the distal third having been most commonly affected in the first mentioned and the proximal third in the latter instance.

Open fractures constitute about 53 per cent of the series. The

relatively least numerous in femur fractures, only one out of 18, and most numerous among the fractures of ulna and humerus. War induced fractures have been included among the open fractures, but they have furthermore been separately grouped by the different bones.

TABLE 2
Presentation of the Material

	Location of the non-union							
	Humerus	Both bones of forearm	Radius	Ulna	Femur	Tibia	Total	Per cent
Number of patients	23	12	13	23	18	71	160	
Sex								
Male	21	10	12	21	11	63	138	86
Female	2	2	1	2	7	8	22	14
Point of fracture								
Proximal 3rd	4	incl. in	3	14	3	6	27	17
Middle 3rd	10	radius or	5	11	11	41	[illegible]	47
Distal 3rd	9	ulna	17	10	4	24	57	36
Initial conditions								
Open fracture	15	5	7	16	1	40	84	53
War induced fracture	7	1	4	12	1	12	37	23
Open reduction performed	4	9	3	4	10	17	[illegible]	29
Previous infection	11	1	3	7	2	25	49	31
Operations for non-union prior to admission into our hospital								
One operation	4	2	4	11	6	20	47	29
Two operations	3		1		1	4	9	6
3 or more	2	1		2		5	10	6
Patients altogether	9	3	5	13	7	29	66	41
Average interval between occurrence of fracture and operation for non-union in our hospital, months	49	21	39	98	18	43	4	

Cases with associated infection have been treated as one single group independent of whether the initial wound or an operation performed prior to admission into our hospital was responsible. No distinction has either been made between already effaced infections and those still present on admission. At all events the infection frequently delayed the non-union operation proper, because the operation was not undertaken until 4 to 6 months after the disappearance of the infection.

Primary operative measures had been taken that is open reduction and osteosynthesis by different fixing methods had been performed on 47 patients (29 per cent) and actual operation intended for the correction of non union had been performed on 66 patients (41 per cent) prior to their admission into our hospital On 19 of the latter patients more than one corrective attempt had been made

It would be interesting to study the length of the time in which positive non union developed in each particular instance The series does not furnish any direct answer to this question because as a rule the patients have still been under treatment in another hospital at the time in question However in Table 2 the average time from incurrence of the fracture to the first corrective operation in our hospital is listed

HUMERUS

There were altogether 23 patients with non union in the upper arm but five of them refused corrective operations and one insisted on amputation owing to great pain this was conceded as the patient furthermore had lesions of the radical and median nerve Altogether 18 corrective operations were done on 17 patients

TABLE 3

Operations for Non union of the Humerus

Method	Number of patients	Union successful	Failure	Cause of Failure	
				Infection	Resorption
Z resection	15	13	2	1	1
Onlay graft	2	2			
Phemister type graft	1	1			

Reoperated with graft

Resection with fixing either with Parham band or with two screws was done 15 times union failing to occur in two of the cases In one of them incomplete fixation produced resorption at the fragment ends but reosteosynthesis with onlay graft resulted in union The other patient with infection responsible for the failure refused another operation and continued to use the supporting bandage he had had previously

The operations resulted in union in 16 patients and none of them retained a faulty position The permanent shortening of the upper arm due to Z resection was considerably (10–15 cm) in three patients and fairly remarkable (5–9 cm) in three in the others it was less Stiffness

of the shoulder joint increased from the preoperative condition in three and that of the elbow joint in two patients. Particularly non-union in the lower third of the humerus tended to leave a permanent restriction of motion in the elbow joint, but not one of the patients was caused very great inconvenience on account of this.

BOTH BONES OF THE FOREARM

There were 12 patients with non-union of both bones of the forearm. For two of them corrective operation was not considered indicated as the functional ability of their hand was almost nil after a serious open fracture and subsequent infection. In ten patients altogether twelve corrective operations for non-union were performed and union was achieved in all cases.

TABLE 4

Operations for Non-Union of the Forearm

Method	Number of patients	Union successful	Failure	Cause of failure Resorption
Z resection	3	2	1	1
Graft	7	6	1†	1
Medullary Nail & Graft	2	2		

Reoperated with graft.
† Reoperated with medullary nail and graft.

In one of the three Z resections union failed to occur owing to resorption of the fragment ends, but union was achieved on reoperation with graft. Of the seven graft osteosyntheses one was a failure due to resorption of the ends of the fragments and of the graft. In this case also reosteosynthesis with medullary nail and graft was successful. Inadequate fixing of the fragments was responsible for the resorption in both instances. On Z resection both osteosynthesis points had been fixed with only one Parham band, while in the other case the transplant had partly been split when it was fixed and therefore failed to provide sufficient stability although four vitallium screws were used. This instance of osteosynthesis also differed from the normal procedure in that osteosynthesis was only performed on the ulna and the proximal fragment of the radius in its entirety was removed at the same time as *the non-union was of considerably proximal location. In one further* operation also a departure from the conventional method was made in the respect that osteosynthesis was only performed on the ulna and

the non union faces of the radius were resected deliberately leaving a non union In this case too a functionally good result was achieved

Union took place in all operated patients and no detrimental faulty positions remained The shortening of the forearm was considerable 4 cm and 8 cm respectively in two cases About the same mobility of elbow joint and wrist as at the time when the non union operation was decided upon was restored in all cases *For increased rotation of the forearm* resection of the distal end of the ulna was performed on one patient and was to be done on another but the latter did not consent

RADIUS

There were 13 patients with non union only of the radius and a corrective operation was performed on twelve of them For one patient the operation was considered unnecessary because he had become accustomed for nearly ten years to the non union which was moreover painless Altogether 13 corrective operations were performed

TABLE 5

Operations for Non Union of the Radius

Method	Number of patients	Union successful	Failure	Cause of failure: Fracture of the graft
Graft	10	9	1	1
Medullary Nail & Graft	1	1		
Z resection & ulnar osteotomy	2	2		

Reoperated with medullary nail and graft

An onlay or inlay graft was employed ten times it was fixed either with Parham band or with screws In one of these cases there was no union resorption took place in the transplant at the point adjacent to the non union and it broke obviously due to stress Reoperation with medullary nail and graft fixed with screws resulted in union also in this case Ulnar osteotomy followed by Z resection of both bones of the forearm was performed in two cases This procedure was chosen on account of a very faulty position of the forearm which would not have been possible to correct without ulnar osteotomy Even so one of the patients has a residual faulty position but this is the sole case with a permanent faulty position in this group

The motions of elbow joint and wrist were otherwise restored to about the condition prior to operation except that rotation of the forearm was almost without exception more or less restricted. In order to improve rotational mobility resection of the distal end of the ulna was performed in four cases.

ULNA

There were altogether 23 patients but no corrective operation was undertaken in eight cases, either for the reason that the non-union caused very little inconvenience, or because the patient himself did not wish to be operated, or because the non-union was so heavily aggravated as a result of suppuration and bone defect that operation was not thought to have any chance of success. 15 patients were subjected to 17 corrective operations.

TABLE 6

Operations for Non-Union of the Ulna

Method	Number of patients	Union successful	Failure	Cause of failure: Infection	Other reason
Graft	14	9	5	2	3
Medullary Nail & Graft	3	1	2	1	1

Two cases reoperated with medullary nail and graft.

In five of the 14 patients operated by the grafting method union failed to occur, which is a relatively high proportion. This was obviously due to the fact that all cases were initially open fractures, moreover three of them were previous war-induced wounds, and manifest infection had been present before in all of them. In three cases resorption of the graft occurred, obviously not due to incomplete fixing but to the poor osteogenetic capacity of the fragment ends. Two of the cases in which union failed to occur were reoperated with medullary nail and graft. Union was successful in one case but the other retained permanent non-union, as did also a third patient initially operated by this method.

In none of the ten cases with successful union was there any permanent faulty position and mobility of the elbow joint and wrist was not impaired from the condition prior to operation. For improved rotation resection of the capitulum radii was performed on altogether six patients either simultaneously with the osteosynthesis or at a later stage.

FEMUR

There were 18 patients belonging to this group Three of them were not operated one owing to poor condition caused by pulmonary tuber culosis and renal insufficiency two others because they were psychi cally unfit to be subjected to a major operation requiring prolonged immobilization On 15 patients 16 operations for non union were per formed one of them having non union of both femora

TABLE 7
Operations for Non Union of the Femur

Method	Number of patient	Union successful
Z resection	5	5
Graft	6	6
Medullary Nail & Graft	4	4

Z resection was carried out in the case of a patient with non union of both femora and the shortening of the extremities due to the opera tions caused no inconvenience for this reason The same method was applied in the case of a patient with congenital dislocation of the oppo site hip and consequent shortening of the leg so that Z resection fur nished at the same time a means of equalizing the previous difference in length In the other two cases there should not have been any well justified reason in our opinion to employ this method in view of the fact that the patients retained the drawback of a leg shorter by 6 cm and 5 cm respectively

For immobilization a hip cast was employed in all cases except in two with medullary nailing and graft in which no plaster at all was applied Union was successful in all operations A faulty position ensued in one case with grafting obviously owing to premature stress Harmful stiffening of the knee resulted in one case and for its correc tion a quadricepsplasty was performed by which the knee mobility of 180 90 was attained

TIBIA

Altogether 71 patients have been under treatment in our hospital for non union of the tibia No corrective operation was undertaken in 14 of these cases amputation on account of severe infection was performed in two and the other twelve were not operated because

The motions of elbow joint and wrist were otherwise restored to about the condition prior to operation except that rotation of the fore arm was almost without exception more or less restricted In order to improve rotational mobility resection of the distal end of the ulna was performed in four cases

ULNA

There were altogether 23 patients but no corrective operation was undertaken in eight cases either for the reason that the non union caused very little inconvenience or because the patient himself did not wish to be operated or because the non union was so heavily aggravated as a result of suppuration and bone defect that operation was not thought to have any chance of success 15 patients were subjected to 17 corrective operations

TABLE 6

Operations for Non Union of the Ulna

Method	Number of patients	Union successful	Failure	Cause of failure: Infection	Other reasons
Graft	14	9	5	2	3
Medullary Nail & Graft	3	1	2	1	1

Two cases reoperated with medullary nail and graft

In five of the 14 patients operated by the grafting method union failed to occur which is a relatively high proportion This was obviously due to the fact that all cases were initially open fractures more over three of them were previous war induced wounds and manifest infection had been present before in all of them In three cases resorption of the graft occurred obviously not due to incomplete fixing but to the poor osteogenetic capacity of the fragment ends Two of the cases in which union failed to occur were reoperated with medullary nail and graft Union was successful in one case but the other retained permanent non union as did also a third patient initially operated by this method

In none of the ten cases with successful union was there any permanent faulty position and mobility of the elbow joint and wrist was not impaired from the condition prior to operation For improved rotation resection of the capitulum radii was performed on altogether six patients either simultaneously with the osteosynthesis or at a later stage

enough in any instance to require corrective measures Total arthrodesis of the ankle was made in three cases on account of ankle pain and restriction of motion in the ankle ensuing from the prolonged treatment Three further patients retained a permanently restrictive mobility of the knee to the extent that flexion to a right angle was impossible One of the cases with unsuccessful union had an infection of such severity that amputation in the upper part of the leg had to be carried out later The ultimate condition of the other failures was the same as prior to operation

RESULTS AND DISCUSSION

It can be seen from Table 9 that 98 of 126 operated non unions or 78 per cent showed successful union after the first corrective operation The corresponding figure in the series of 842 patients of *Boyd et al* (1961) is 88 per cent Repeated corrective operations raised the ultimate result in our series to 110 successfully treated non unions or 87 per cent against 94 per cent in Boyd s series It may also be mentioned for the sake of comparison that the percentage of ultimately successful unions in the series of 126 patients of *d Aubigne* (1949) was similarly 94 per cent Quite certainly the ultimate percentage of successful union would have been higher in our series too if all patients with an unsuccessful first operation had been reoperated However only 19 of 28 such patients were reoperated nine of them declining any further measures

Scrutiny of the 36 cases in which the first corrective operation (in 28 cases) or repeated operation (in 8) failed to produce union reveals that infection was responsible in 11 cases This may appear a high proportion but it is largely due to the fact that there was an infection prior to the corrective operation in 31 per cent of the whole series The infection probably continued in a latent form in most instances and became inflamed in connection with operation in spite of all precautions The relatively highest incidence of infection was recorded for the ulna the non union operations on the tibia ranging next

About 80 per cent of the operated persons were given prophylactic antibiotic treatment most frequently by penicillin injections In earlier years this was not administered but nowadays it is considered pertinent in our hospital

Fracture of the graft subsequent to operation occurred altogether six times and was obviously the cause of failure in the cases in question

TABLE 9

Results of operation, time required for union to take place and periods of incapacitation

	Location of the non-union							
	Humerus	Both bones of forearm	Radius	Ulna	Femur	Tibia	Total	Per cent
Number of patients	17	10	12	15	15	57	126	
Result of 1st operation								
Union successful	15	8	11	9	15	40	98	78
Failure	2	2	1	6		17	28	22
Result of 2nd or last subsequent operation								
Union successful	1	2	1	1		7	12	
Failure				1		7	9	
Number of patients with successful union	16	10	12	10	15	47	110	87
Time for union to take place (immobilization period), weeks								
Range	8–29	15–30	13–26	13–28	6–46	14–38		
Mean	17	24	19	21	30	23		
Period of incapacitation after successful operation, months								
Range	3–15	4–13	5–10	5–16	2.5–15	0.5–5		
Mean	8	8.5	6.5	7.5	8	8.5		

five of them concerning the tibia and one the radius In the last mentioned instance there had been a faulty position which had been corrected at the operation but there had probably been residual stress on the graft gradually leading to its fracture In three of the cases of fractured tibial graft walking had been commenced without walking cast this probably produced stress fracture of the graft and therefore failure of treatment Since 1956 our hospital has applied the rule of interposing a walking cast stage after union has taken place in the after treatment of an osteosynthesis in the lower extremity which is continued until osteoporosis has disappeared It has not been positively clarified from which agents the fracture in the other unsuccessful tibial grafts resulted

The other causes for failure of the bones to unite have been highly variegated and it is frequently impossible to point out the ultimate cause of failure Usually several unfavourable partial factors together have contributed to a poor end result Among them there may be mentioned insufficient fixation strong sclerosis of the fragments and too sparing use of spongeous bone

No attempt at mutual comparison of the results obtained by different operating methods has been attempted for the reason that as a rule the principle was to employ the technique that was considered most appropriate in each instance So far the treatment of non union has not been solved by any single method of treatment it is rather a fact that different states and conditions require different measures In order that the best possible results may be achieved not only complete mastery of the surgical technique is required but there should also be good surgical judgment If these conditions exist the results obtained by different techniques will be largely similar

SUMMARY

In the Orthopaedic Hospital of the Invalid Foundation 160 patients were under treatment during the period 1945 1960 for non union of the shafts of one of the long bones in the extremities The initial cause of non union was open fracture in 53 per cent of the cases and one or several operations for correction of non union had been performed prior to admission into our hospital in 41 per cent of the cases There had been infection in altogether 31 per cent of the cases

Corrective operation for non union was performed on 126 patients and successful union was achieved in 110 (87 per cent) although 12

patients required more than one operation The operative method varied according to circumstances no positive differences between the methods can be seen on the strength of this series

RESUME

A l Hopital Orthopedique de la Fondation des Invalides, 160 malades ont ete traites durant la periode 1945 1960 pour une non soudure de la diaphyse des os longs des extremites La cause initiale de la non soudure etait une fracture ouverte dans 53 pour cent des cas Une ou plusieurs operations en vue d obtenir la soudure avaient eté pratiquées avant l admission dans notre hopital dans 41 pour cent des cas Il y avait eu des infections dans 31 pour cent des cas

Une operation corrective fut pratiquee chez 126 malades et la soudure a ete obtenue dans 110 cas (87 pour cent) bien qu il ait fallu plus d une operation chez 12 malades La methode operatoire a varie selon les circonstances En se basant sur cette serie de cas il n a pas ete constate de differences positives entre les methodes

ZUSAMMENFASSUNG

Im Orthopädischen Krankenhaus der Invalidenstiftung sind während der Zeit 1945 1960 160 Patienten wegen Pseudarthrose eines der langen Rohrenknochen der Extremitaten behandelt worden Die Original ursache der Pseudarthrose war offener Bruch in 53 Prozent der Falle und eine oder mehrere Operationen zum Korrigieren der Pseudarthrose sind in 41 Prozent vor dem Einliefern in unser Krankenhaus ausgefuhrt worden Infektionen sind in insgesamt 31 Prozent vorhanden gewesen

Operation zur Behebung der Pseudarthrose wurde bei 126 Patienten vorgenommen mit Wiedervereinigung der Knochenbruchstucke in 110 Fallen (87 Prozent) obwohl bei 12 Patienten mehr als eine Operation notwendig war Die Operationsmethoden variierten je nach den Umstanden und es ist an Hand des vorliegenden Materials kein deutlicher Unterschied zwischen den verschiedenen Vorgehen zu verzeichnen

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THE GRICE OPERATION FOR PARALYTIC FLAT FEET IN CHILDREN

By

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INTRODUCTION

Arthrodesis of the ankle joint and subastragalar joint is a procedure which has been used for a long time for the purpose of correcting and stabilizing feet paralyzed and deformed by poliomyelitis.

As early as 1879 *Albert* of Vienna performed an arthrodesis of the ankle joint in order to stabilize a paralyzed foot, and in 1905 *Nieny* did a subastragalar arthrodesis. Since then, numerous reports on arthrodeses of paralytic feet have been published, and a number of different techniques have been employed. Subastragalar arthodesis, as generally performed, often requires resection of a good deal of bony tissue, especially when performed on flat feet. In children it has been used only with some hesitation for fear of disturbing growth.

In 1952, however, *Grice* described a procedure for subastragalar fixation of paralytic flat feet in children consisting in extra-articular fixation inserting a bone graft into the sinus tarsi. In his first paper he reported favourable results, but the follow-up period did not exceed 2 years. In 1955 *Grice* reported his further experience, now after 1–5 years follow-up, and the results were still satisfactory.

At the Orthopaedic Hospital, Copenhagen, we have used the Grice operation for paralytic flat feet in a number of cases from the great polio epidemic in 1952. By now, the follow-up period is sufficiently long for assessing the results. The present report deals with the follow-up findings and the conclusions which they seem to warrant.

MATERIAL

Sixty six children with paralysis of the feet after poliomyelitis were submitted to a total of 69 Grice operations at the Orthopaedic Hospital Copenhagen during the period 1955–57

TABLE 1
Sex and age distribution of 66 children who had the Grice operation for paralytic flat feet

No of children	29 37	No of feet 69
	Age at operation	
	4–6 years	22 feet
	7–9 years	28 feet
	10–12 years	19 feet

In all cases the deformity was plano-valgus or calcaneo valgus Table I giving the sex and age at operation shows that the age ranged from 4 to 12 years the majority being from 4 to 9 years 29 were girls and 37 boys

All the patients had been infected with polio in 1952 and the operations were carried out from 2 to 5 years in most cases about 3 years after the acute illness This gives a follow up period of from 4 to 6 years

All the patients were after examined by the author in early 1961 The examination included subjective and objective clinical assessment and X ray investigations

METHOD

The procedure was that described by *Grice* (1952) inserting 2 autogenous bone grafts from the tibia into the sinus tarsi (Figs I II III IV)

After treatment consisted in a plaster cast for a total of 12 weeks without weight bearing for 4 weeks and with weight bearing for 8 weeks Thereupon orthopaedic footwear arch supports or in a few cases foot capsule according to the shape of the foot and paralyses in other muscles of the leg were utilized In several cases tendon transplantations were carried out to stabilize the position lengthening of the heel cord was done where it seemed necessary



Fig 6
The same foot as Fig 5 2½ years later Incipient absorption of the grafts



Fig 7
The same foot as Fig 5 5 years later The grafts have been completely absorbed

the fixation must be due to fibrous adhesions in the sinus tarsi In 2 instances there was a question of incorrect technique the grafts having been inserted into the wrong place and having been completely absorbed (Figs V, VI and VII) In the other cases with deficient healing of the grafts perusal of the case records did not afford any explanation It must be mentioned that in our cases where healing was deficient this was always at the astragalus

TABLE 3
Clinical and radiological fixation at follow up on 69 paralytic flat feet treated by the Grice procedure

	Subastragalar fixation at follow up	
	Clinical	X ray
Fixation	64	51
No fixation	5	18
Total No	69	69

In assessing the X ray appearances it is important to note the relationship of the astragalus to the calcaneus It is impossible to decide to what extent the A C angle has been corrected by the operation since regrettably no preoperative films were available for a large proportion of the patients However since the operation was carried out to correct flat foot the A C angle has presumably been increased in the great ma



Fig 8
A large A C angle in paralytic flat foot



Fig 9
The same foot approx 5 years after a successful Grice operation Now the A C angle is smaller than normal

jority of cases In those cases where preoperative X rays were available there had been a distinct diminution of this angle (Figs VII–IX)

Follow up showed a normal A C angle in 22 cases In 17 cases it was 10 –30 in 20 cases it was < 10 and in 6 cases 0 Only 4 had an abnormally wide A C angle

The explanation why so many patients showed clinically uncorrected or increased valgus deformity at follow up despite a normal or even reduced A C angle and subastragalar fixation must be that a large proportion of them had instability of the ankle joint and Chopart s joint Even in clinically satisfactory cases some patients may show a trace of instability of the ankle joint

Out of 23 patients with poor results 18 had marked instability of the ankle joint and a varying degree of instability of Chopart s joint Out of the 46 cases with a good result 8 had slight instability of the ankle joint which may be feared to progress in the years to come Thus out of the total series of 39 feet 26—or 38 %—had more or less tendency to instability of the ankle joint and often also of Chopart s joint

In 11 patients mainly those with poor results and instability of the ankle joint follow up revealed tightening of the heel cord Eighteen of

the total series had lengthening of the heel cord performed either at the time of the Grice operation or somewhat later

TENDON TRANSPLANTATIONS

About two thirds of the patients had tendon transplantations in addition to the Grice operation for the purpose of correcting the muscular imbalance and thereby preventing a recurrence of the deformity Table IV shows the type of transplantation

TABLE 4
Different types of tendon transplantation done in connection with the Grice operation

Results in cases with and without tendon transplantation			
Type of transplantation	Total no	Good	Bad
Strengthening of heel cord	7	6	1
Strengthening of ant and/or post tib	18	12	6
Peron long or brev to dorsum ped	15	6	9
Others	4	4	0
Total No with tendon transplant	44	28(63.6 %)	16
Without tendon transplantation	25	16(64 %)	9

It will be seen that the result of the operation is the same in both groups and therefore gives no indication of the value of supplementary tendon transplantation

TABLE 5
Analysis of instability in the ankle joint following the Grice operation in relation to tendon transplantations

Tendon transplantation in relation to stability of the ankle joint			
	Stable	Unstable	Total
With transplant	30 (68 %)	14	44
Without transplant	13 (52 %)	12	25
Total No	43 (62 %)	26	69

*Tendon transplantation must in all cases affect the lateral and me*dial muscles whether the transplantation is posterior anterior or contralateral It is of importance therefore to ascertain whether tendon transplantation is of any significance to secondary instability of the ankle joint This is shown in Table V which reveals a far larger number

of unstable cases without tendon transplantation than with tendon transplantation. A possible explanation is that it has been predominantly in cases of severe paralysis that tendon transplantation has not been performed.

MUSCLE POWER IN RELATION TO RESULTS

From what has been stated above it will be understood that an important cause of the poor results was secondary instability in the ankle joint. The following figures set out the relation of this sign to muscle power assessed at follow up. In other words the assessment includes tendon transplantations if performed.

Table VI gives the results in cases of sufficient and insufficient triceps. There is no difference.

TABLE 6

Analysis of results following the Grice operation in relation to the strength of the triceps

Muscle power [illegible] results (According to the international grading) into [illegible]	Good	Poor	Total
Triceps 3 or more	33	15	48
Triceps below 3	13	8	21
Total No	46	24	69

Table VII shows the significance of the lateral and medial muscles. Clearly the strength of these muscles is of the utmost importance to the results, there being only one poor result out of 17 where they were sufficient on both sides, while two thirds were poor where these muscles were insufficient.

TABLE [illegible]

Analysis of the results following the Grice operation in relation to strength of peronei and ant. and post. tibialis respectively

Muscle power in [illegible] to results (According to the international grading) into [illegible]	Good	Poor	Total
Peronei 3 or more, ant. et post. tib. below 3	23	9	32
Peronei below 3, ant. et post. tib. 3 or more	1	1	2
Both 3 or more	16	1	17
Both below 3	6	12	18
Total	46	23	69

DISCUSSION

From this analysis it is evident that the Grice operation in our hands with a follow up period of 5 years has given good results in two thirds of the cases

When deducting cases in which there were technical errors at the operation or deficient healing of the graft for other reasons the main cause of the poor results was instability of the ankle joint and of Chopart s joint Furthermore a number of the feet which are satisfactory at present may be expected to develop instability in the course of the next few years

In his first paper *Grice* mentioned only one case in which the result was compromised by instability of the ankle joint The follow up period was then only 2 years In his second paper with follow up periods up to 5 years he had 3 cases In his opinion the explanation was tightening of the heel cord This accords well with the present author s findings as 11 of the poor results had tightening of the heel cord at follow up

Westin (1957) in a series of 31 cases had no unstable ankle joint However he had 3 with plano valgus deformity and tightening of the heel cord so that possibly the deformity was in actual fact due to instability of the ankle joint

It is a common opinion that arthrodesis often leads to excessive strain and consequent instability and possibly oseoarthritis in neighbouring joints *Robins* (1959) however found instability of the ankle joint in only 15 % of cases submitted to subastragalar arthodesis for the sequelae of poliomyelitis in young persons and *Lindholm* (1960) reported instability of the ankle joint in only 2 out of 36 adult polio feet after subastragalar arthrodesis In the present series however the operations were performed on younger children and this perhaps accounts for the difference in the results

That muscle power *per se* is of great importance is beyond doubt *Where the lateral and medial muscles were sufficient nearly all the results were good* while with insufficient lateral and medial muscles practically all were poor

Primarily there is imbalance between the posterior and anterior tibialis on the one hand and the peronei on the other as this is what makes the deformity develop and the sufficiency—or more correctly—the balance has been created by tendon transplantations primarily activation of the anterior or posterior tibialis An active posterior tibialis

may be obtained by transplanting the peroneus brevis to this tendon This procedure however very often yields poor results either in the form of over correction or locking effect while activation of the anterior tibialis by all the toe extensors generally gives good results (*Zacharıae* 1961) and is to be recommended

Whether the Grice operation is to be considered a final procedure or has to be followed by subastragalar arthrodesis or panarthrodesis about the age of 14 is difficult to say at present The latter is indicated by many findings int al instability of Chopart s joint and the ankle joint In that case it must be seriously considered whether the same result might not have been obtained by tendon transplantation alone and whether in that case the secondary instability of the ankle joint might have been avoided

SUMMARY

A follow up study on 69 paralytic flat feet treated by the Grice operation is reported All the patients were from the 1952 polio epidemic underwent operation 2–5 years after the acute illness and were followed up 4–6 years after the operation Good results were found in two thirds but a large proportion had secondary instability of the ankle joint possibly due to tightening of the heel cord Tendon transplantation had been carried out in two thirds The various types of this procedure are discussed and transplantation of all toe extensors to the anterior tibialis is recommended The muscle power in the lateral and medial muscles is of great importance to the results and it is suggested that in a number of cases the surgery might presumably have been restricted to tendon transplantation alone

RÉSUMÉ

Compte rendu de l examen complementaire de 69 cas de pieds plats paralytiques traites par l operation Grice Tous ces malades avaient ete atteints par l épidemie de poliomyelite de 1952 L operation fut pratiquée 2 à 5 ans apres le stade aigu de la maladie et les malades furent réexaminés 4 à 6 ans après l operation Chez les deux tiers on trouva des résultats satisfaisants mais avec une large proportion d instabilite secondaire de l articulation de la cheville peut-etre due à l épaississement des tendons du talon Une transplantation de tendons a ete pratiquée chez les deux tiers de ces malades

Il est discuté des differents types de procédes et la transplantation

de tous les extenseurs des orteils au tibia anterieur est recommandee *La force musculaire du muscle lateral et medial est d une grande im* portance pour le resultat et il est suggere que l on aurait pu se limiter a la seule transplantation des tendons dans un certain nombre de ces cas

ZUSAMMENFASSUNG

Über eine Nachuntersuchung von 69 Lähmungsplattfüssen die mit tels der Operation nach Grice behandelt wurden wird berichtet Alle Patienten kamen von der Poliomyelitisepidemie 1952 wurden 2–5 Jahre nach Ablauf der akuten Erkrankung operiert und wurden 4–6 Jahre nach der Operation kontrolliert Gute Ergebnisse wurden in zwei Drit teln gefunden aber eine grosse Anzahl hatte eine sekundäre Instabilitet des Knöchelgelenkes moglicherweise wegen Anstrammung der Achilles sehne Sehnenverpflanzung wurde in zwei Dritteln vorgenommen Die *verschiedenen Arten des Vorgehens werden besprochen und die Ver* pflanzung aller Zehenstrecker zum m tibialis anterior wird anbefohlen Die Muskelkraft der lateralen und medialen Muskeln ist von grosser Wichtigkeit und man nimmt an dass man sich in einer Anzahl von Fällen mit Sehnenverpflanzung allein hätte begnügen konnen

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EXPERIMENTAL PROGRESSIVE SCOLIOSIS IN A PIG

By

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INTRODUCTION

In spite of many years of clinical and experimental investigation the biological cause of juvenile idiopathic scoliosis is still unknown The early appearance of the syndrome idiopathic scoliosis often during the first year of life is stated to be a characteristic one With few exceptions idiopathic scoliosis is progressive resulting in disablements with compensatory rebuilding of the vertebral column

Scoliosis has been produced experimentally in animals but the induced injury was applied to different sites and degrees in the vertebrae and changes corresponding to those in juvenile scoliosis in man were not been demonstrated

Knutsson has suggested a theoretically sound hypothesis of its cause and progress based on a survey of experimental work He pointed out the dualistic development of the vertebra during normal growth

By analogy with the bones of the extremities the vertebral bodies grow during the whole period of development of the individual In man this growth is not complete until the age of 18 to 20 years By analogy with the cranium the vertebral arch grows rapidly from the ages of 3 to 5 years but already by the age of 1 year the two arches are united by bone The growth then takes place only in the neuro-central junctions towards the vertebral body and is complete at the age of 10 years

As a result of this the symmetry of the vertebral arch is due to equal growth of the two neuro-central junctions towards the vertebral body If this growth proceeds asymmetrically during the first decade because of premature closure of the neuro central junction ventral displacement of the vertebral body on this side does not occur The arch on the opposite side grows however and like a train buffer dislocates the part



Fig 1
Assymetrical growth of *Th 8* from child with a scoliosis to the right Fused neuro central junction on the convex side open on the concave side The vertebral body rotated towards the convexity (Taken from Nicoladoni s publication)

of the vertebral body in front which is thus rotated ventro contra laterally (*Schede Knutsson*)

This asymmetry in development of the vertebral arches and mal rotation of the vertebral bodies was described in anatomical studies of scoliotic vertebrae from postmortem material in infantile scoliosis (*Nicoladoni*) Four cases 1 6 6½ and 7 years of age are described The following common changes in the scoliotic vertebrae are found (Fig 1)

1 The development of the neuro central junctions was asymmetrical Well developed and completely open neuro central junctions were found in the concavities of the scolioses In the convexities of the scolioses the junctions were thinner (1 6 years of age) and there appeared interruptions in continuity synostoses (6½ 7 years)

2 The arches in the concavity were long and fine whilst those on the convexities were *short and irregular*

3 The vertebral bodies were rotated towards the convexity of the scolioses with the centre of rotation in the ossified neuro central junction

Thus the vertebral bodies are forced out of their static relationship with those above and below and are rotated laterally The resulting scoliosis is combined with a lordosis because of changes in the loading conditions Later they are secondarily distorted in the scolioses (*Sommerville*)

Premature closure of one neuro central junction resulting from injury may explain the initial phase of infantile scoliosis The resulting

changes in loading would then produce secondary compensatory curvatures as a normal biological response

OPERATIVE PROCEDURE AND RESULTS

As mentioned in the introduction injuries to the vertebral arches processes and bodies have been carried out in animals (*Haas Langenskiold Moser Pacher Roaf*) However the neuro central junctions were unintentionally involved either partially or completely by these procedures

In the following an account is given of unilateral experimental injury to the neuro central junction in an isolated lumbar vertebra of the pig For technical reasons experiments were carried out in the lumbar region The vertebrae of a pig are well developed in this region and growth is rapid during the first months of life The vertebral arches are wide and easy of access

Using a rotating dental drill with a diameter of 1½ mm a unilateral neuro central junction was injured in a 28 day old pig A para vertebral incision was made and the drill was inserted to a depth of ½ cm into the right neuro central junction in the caudal part of L2 without da

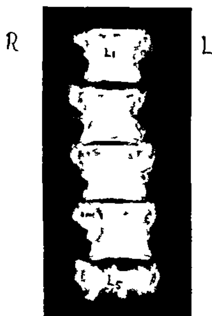
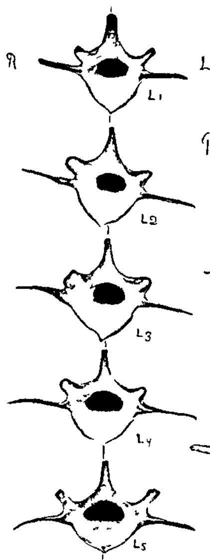


Fig 9
Frontal radiogram L1 L5 from pig 3 months of age A slight scoliosis with the convexity to the rigth is seen after an isolated injury to the right neuro-central junction of L





Figs 3

L_1–L from the same pig as in Fig 2 The vertebral bodies rotated to the right in L_1–L_4 and the right arch is short and irregular

Fig 4

L cut in horizontal slices from the same pig as in Fig 2 3 Fusion of the injured right neuro central junction in its lateral region Short irregular arch on this side The vertebral body rotated to the right

mage to the L2–L3 disc The drill was then moved cranially and bored a canal within the junction It was removed before reaching the L1–L2 disc The L2 vertebra was marked with a small wire suture at the tip of the spine and the wound was then closed

After three months the animal was killed the increase in weight during this time being 32 kilos (8–40) The lumbar vertebrae were dis *sected out and a frontal radiogram was taken (Fig 2) On this is seen* a slight scoliosis convex to the right involving the whole lumbar re gion but without a centre of rotation The vertebrae L1–L5 were then dissected free and the architecture was studied roentgenologically (Fig 3) Not only did the operatively injured L2 vertebra show pathological changes but also L1 L3 and L4 showed common specific changes In the convexity of the scoliosis the arches are irregular and short whilst the opposite concave ones are fine and longer Except for L2 the neuro central junctions are completely visible and roentgenologically equal For more detailed studies of vertebra L2 it was necessary to cut hori zontal slices 2–3 mm thick which are shown in the radiogram (Fig 4) Besides the above mentioned changes the neuro-central junction on the convex side was affected In the most caudal slice a small defect could be seen corresponding to the site of the drill during the operation In the next two slices there was a fusion in the lateral half of the neuro central junction and growth had ceased The medial half of the neuro-central junction can still be clearly seen

DISCUSSION AND CONCLUSIONS

As described above the scoliosis produced surgically in the pig corre sponds closely to infantile scoliosis in man (*Nicoladoni*) The damage *to the neuro central junction of L2 followed by premature fusion* produced an asymmetrical growth of the arch with a secondary ro tation of the vertebral body towards the fused side The disturbance in static relations hereby produced reacted biologically on the surrounding vertebrae distorting them The results obtained from an isolated uni lateral injury to one neuro central junction reported here encourage further experimental investigation e g with apes where the loading relationships in the vertebral column correspond to those in man If it can be shown that scoliosis similar to the above performed experiment can be produced progress of the scoliosis could possibly be stopped by a new operation on the other neuro central junction before the neuro central junctions are united

SUMMARY

The neuro central junction on one side of a lumbar vertebra of a month old pig was injured by drilling During the following 3 months a slight scoliosis developed in the lumbar spine A premature fusion occurred in the injured junction associated with asymmetrical growth of the vertebral arch and rotation of the vertebral body towards the fused side These findings are similar to the changes which have been found in juvenile scoliosis of homo by Nicoladoni

RESUME

Chez un porc âgé d un mois il a eté operé par forage une lesion unilaterale de la jointure de l arc d une vertebre lombaire Au bout de trois mois on a pu constater une scoliose marquee de la colonne lombaire Dans la vertebre on trouva une fusion prématuree de la jointure de l arc endommage une croissance asymetrique de l arc vertebral et une rotation du corps de la vertebre du coté de la fusion Ces modifications sont conformes a celles constatees par Nicoladoni dans la scoliose juvenile humaine

ZUSAMMENFASSUNG

Bei einem einen Monat alten Schwein wurde durch Bohrung auf einer Seite die Knorpelfuge in einem Lendenwirbel beschadigt Nach drei Monaten trat eine angelentete Skoliose innerhalb der Lendenwirbelsäule auf Bei diesem Wirbel fand man eine vorzeitige Verknocherung in der einen beschadigten Knorpelfuge asymmetrisches Wachstum des Wirbelbogens und eine Rotation des Wirbelkorpers nach der Verknocherungsseite Die Veranderungen stimmen mit denen uberein die bei juveniler Skoliose beim Menschen von Nicoladoni beschrieben worden sind

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF FOLKE KNUTSSON) UNIVERSITY HOSPITAL UPPSALA SWEDEN

A CONTRIBUTION TO THE DISCUSSION OF THE BIOLOGICAL CAUSE OF IDIOPATHIC SCOLIOSIS

By

FOLKE KNUTSSON

Idiopathic scoliosis had been thoroughly studied by a number of clinical workers (*Harrenstein, James et al, Nicoladoni, Roaf Scott & Morgan Lindermann, Rathke, Jentschura & Mau*) Included in this definition are those scolioses which appear during the growing years and where no direct cause can be demonstrated The scoliosis can begin during the first three years of life or later the curvatures often increase to severe deformities but in some cases there is a spontaneous return to normal The progressive development is shown in Fig 1 which is derived from the publication of *James* The curvatures appear most often in the lower part of the thoracic spine followed by compensatory curvatures but there are also other kinds Various stabilising operations have been tried to prevent progression but the results have often been unsuccessful Since the biological cause of idiopathic scoliosis is unknown it has not been possible to carry out an adequate causal treatment

A number of points are presented in the present paper which are worthy of consideration in attempts to find the cause of idiopathic scoliosis

The normal growth of a vertebra

A vertebra consists both anatomically and biologically of two different parts body and arch

The vertebral body is analogous to the bones of the extremities increasing continuously during the whole period of growth in length breadth and depth This growth ends first at 18–20 years of age

The vertebral arch on the other hand is analogous to the cranium It grows at the same rate as the cranium The part of the arch which



Fig 1

Idiopathic scoliosis in a boy at 9 and 8 years of age
(Taken from James publication)

constitutes the spinal canal and surrounds the spinal medulla is thus analogous to the cranium which surrounds the brain Apart from the various processes of the arch which continue their growth during the development of the individual the ring around the spinal canal follows at quite a different pace As early as 1–2 years of age both halves of the arch have become unified in bone As a result of this the continued growth leading to increase in breadth of the spinal canal occurs exclusively in the neurocentral junction This growth occurs rapidly during the first 3–5 years of life and then more slowly until 10 years of age when it is complete (*Knutsson*) Thus the ring of the arch has attained its final size by about 10 years of age

There is a risk of conflict in this double development of a vertebra According to the literature growth in the neurocentral junction is complete between 3 and 8 years of age This wide time limit may seem strange This can however be explained if completion occurs at different ages in different parts of the vertebral column No systematic anatomical study of the time of completion in different vertebrae has been carried out and a roentgenological assessment is impossible in practice I have examined two publications in which it is possible to decide from

the films whether the join is complete or incomplete These show that in one child 6½ years of age the join was incomplete in vertebra Th2 Th4 and Th8 but on the other hand complete in Th10 L1 and L2 (*Nicoladoni*) In another child of 3½ years the join was incomplete in vertebrae Th3 and Th7 but complete in C4 and L4 (*Engelmann*) These few observations are in favour of completion occurring at different times in different parts of the vertebral column and furthermore that it occurs last in the thoracic spine Thus the harmonious development of the vertebral column even up to 8 years of age probably depends on the paired neuro-central junctions growing absolutely similarly and being complete at the same time On the other hand if growth is not uniform an asymmetry between arch and vertebral body is to be expected

Growth conflict in paired neuro central junctions

After the age of 1–2 years the symmetrical shape of the arch is completely dependent on growth in the neuro-central junction If this takes place at a different rate and leads to a premature synostosis on one side the vertebral body is twisted out of its harmonious relationship with *the vertebrae above and below Such a unilateral retardation in growth* leads to the distance between the joint processes and body of the vertebra being continually shorter during the time of growth than on the opposite side The conditions required for an normal development of the vertebral column are that growth in the neuro central junctions occurs at the same rate on both sides (Fig 2)

This problem has been dealt with by *Nicoladoni* In a series of dead children with infantile scoliosis aged 1 6 6½ and 7 years he has studied the neuro-central junction This was without exception completely open on the concave part of the scoliotic curvature and completely closed on its convex part or more open and more closed respectively



Fig 2

Diagram of the effect of unequal growth on the neuro-central junctions The vertebral body rotated towards the side where premature synostosis occurs and thus producing scoliotic curvature with the convexity towards this side



Fig 3

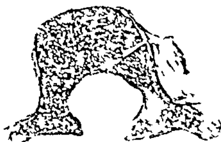


Fig 4

Fig 3 Th8 *in a 6½ years old child with a scoliosis convex to the right* The neuro central junction is completely open on the concave side of the curvature but fused with bone on the convex side The vertebral body is rotated towards the convex side (Taken from Nicoladoni's publication)

Fig 4 Th2 in the same child as in Fig 3 situated in the scoliotic curvature convex towards the left The neuro central junction is completely open on the concave side and almost closed on the convex side The vertebral body is rotated towards the convex side (Taken from Nicoladoni's publication)

Thus growth was more rapid on the concave side causing a prolongation of the peduncle which in its turn produced a rotation of the vertebral body towards the convex side

In one of *Nicoladoni's* cases the 8th thoracic vertebra which was at the apex of the curvature convex to the right showed a completely synostosed neuro central junction on the convex side and one completely open on the concave side (Fig 3) The vertebral body is rotated towards the convex side This change must be ascribed to a retarded and premature growth in the neuro central junction on the convex side The compensatory curvature higher up with Th2 as the apex and with the convexity to the left shows the opposite asymmetry in both neuro-central junctions (Fig 4) If the change in Th8 is considered as primary then the change in Th2 is the biological reaction by which the underlying curvature is compensated for

Schede came to the conclusion that the characteristic change in the scoliotic vertebra can only be explained by an injury to the neuro central junction He has suggested rickets as a possible cause

With the knowledge of the definitely completed growth of the arch at about 10 years of age and the subsequently continuous growth in height of the vertebral body it should be possible to explain the progress of the scoliosis After the vertebral body has rotated in a lateral

direction and the displacement has been combined with lordosis and lateral deviation (*Sommerville*) the conditions of loading are changed The pressure becomes greater on the posterior areas of the vertebral body surfaces than on the anterior areas By this means the vertebral body grows more rapidly in height anteriorly than posteriorly and the curvature increases continuously

Because of this there is reason to suppose that the premature closure of the neuro central junction on one side can initiate a scoliotic curvature and that the adjacent compensatory curvatures are the biological reaction which in their turn produce unequal growth in the other neuro central junctions

One can ask oneself if there is any plausible explanation of why the differing growth in the paired neuro central junctions appears particularly in the thoracic region There is a reason to think that growth in the neuro central junction in this part of the vertebral column continues longest and that closure here can be delayed until 8 years of age This situation may provide a disposing cause

CONCLUSION

Idiopathic scoliosis consists of rotation lordosis and lateral deviation There is evidence that rotation can be elicited by varying rates of growth in the paired neuro central junctions (*Nicoladoni*) Growth in the neuro central junction is complete at different times in different parts of the vertebral column between 3 and 8 years Some observations are are in favour of its continuing longer in the thoracic region than in other parts of the vertebral column In discussing the origin of idiopathic scoliosis one may ask whether a retarded growth in one of the paired neuro central junctions can initiate a scoliosis from the rotation of the vertebral body out of its harmonic relationship to the other vertebral bodies Rotation occurs towards the side in which growth in the neuro central junction is retarded and the scoliosis is convex on *that side (Nicoladoni) From this there exists a theoretical possibility* of inhibiting an increasing rotation during the period of growth by an epiphysiodesis in the neuro central junction on the concave side of the curvature In order for such an epiphysiodesis to be effective it must be carried out at an early stage before the age of 3–5 years In such a way it is theoretically possible to counteract continued rotation and thus the continued increase in the curvature which depends on continued growth in height of the vertebral bodies is inhibited

Further research into this problem is required For this purpose an injury to a neuro central junction could be produced which would lead to premature synotosis to see if a scoliotic curvature would develop There is no such isolated lesion published without simultaneous lesions of growth zones of the vertebral bodies (*Pacher*)

SUMMARY

In spite of extensive clinical and experimental research the biological cause of idiopathic scoliosis is still unknown There is evidence for an unequal growth in the paired neuro central junctions which can lead to rotation of the vertebral body out of its symmetrical relationship in the vertebral column This seems to be one of the ways in which scoliosis can arise The progress of the scoliosis which follows can probably be explained by the continued growth of the vertebral bodies Further experimental research concentrated on isolated neuro central junctions is required to try to produce premature synostosis and to study the effect

RESUME

Malgre des recherches cliniques et experimentales très poussées la cause biologique de la scoliose idiopathique est toujours inconnue On a constate une croissance inégale des jonctions neuro centrales accouplées qui peut conduire a une rotation du corps vertébral hors de son rapport symétrique dans la colonne vertebrale Cela semble etre l une des manieres dont la scoliose peut se produire Le progres de la scoliose peut s expliquer par la croissance continue des corps vertebraux Il est necessaire de poursuivre la recherche expérimentale en la concentrant sur des jonctions neuro centrales isolées pour essayer de produire des synostoses prematurees et d en étudier l effet

ZUSAMMENFASSUNG

Trotz ausgedehnter klinischer und experimenteller Forschung ist die biologische Ursache der idiopathischen Skoliose noch immer unbekannt Es bestehen Anzeichen fur ein ungleiches Wachstum der gepaarten neuro centralen Verbindungen das zu einer Herausdrehung des Wirbelkorpers aus seiner symetrischen Lage in der Wirbelsäule fuhren kann Dies scheint eine der Moglichkeiten zu sein die eine Skoliose hervorrufen kann Das folgende Fortschreiten der Skoliose kann wahrscheinlich durch das fortgesetzte Wachstum des Wirbelkörpers

erklärt werden Weitere Untersuchung die ihre Aufmerksamheit be sonders auf die neuro centralen Verbindungen richten und versuchen sollte vorzeitige Synostosen hervorzubringen und deren Wirkung zu studieren ist nötig

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WILL PLANE FILM EXAMINATION OF LUMBAR SPINE BE A RELIABLE METHOD TO EXCLUDE OR DISCLOSE RUPTURED DISCS?

A plane film examination of 1055 lumbar intervertebral discs is compared with discographic discovery such as discogram and verified past history pain

By

ULF FERNSTRÖM

INTRODUCTION

Previous examinations show that plane film examination of the lumbar spine gives sources of error when excluding or disclosing disc degenerations These examinations are based upon section material (*Friberg* 1947 *Friberg & Hirsch* 1950) cases operated on for lumbar herniated disc (*Malmros* 1942 *Norlen* 1944 *Waris* 1948 *Rovig* 1949) and discographed cases *Perey* 1951 *Crassberger & Seyss* 1955 *Witt* 1954 *Norlander Salen & Unander Scharin* 1958) Despite this plane film examination of the lumbar spine tends to become one of the most common examinations (*Larsson* 1958) and it is also believed that this examination may serve as a guide to determine the origin of pain (*Vara & Waris* 1951 and 1952 *Brailsford* 1955) On the basis of this I have found it appropriate to study further the reliability of this method for use in lumbar disc degeneration Plane film examination will be compared with discographic findings such as discograms and verified past history pain This investigation differs from earlier ones as much as it comprises all the lumbar disc levels

SERIES

The series includes 279 cases 147 males (16–66 years) and 132 females (14–65 years) with low back pain and/or sciatica In 80 cases there were no signs of the nerve root being involved Comparative exa

erklärt werden Weitere Untersuchung die ihre Aufmerksamkeit besonders auf die neuro centralen Verbindungen richten und versuchen sollte vorzeitige Synostosen hervorzubringen und deren Wirkung zu studieren ist notig

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or complete) and which at puncture or contrast medium injection causes pain identical with the past history pain can be regarded as the origin of pain (*Lindblom* 1948, 1950, *Cloward & Buzaid* 1952, *Cloward* 1952, 1953, 1955, 1959 and *Fernström* 1960). That type of rupture has here been called painprovoking rupture (PPR). Whether or not this rupture shows nerve root compression cannot be determined on the discogram (*Fernström* 1960) but is of no importance to this investigation as nerve root compression is unnecessary (*Cloward* 1959, *Fernström* 1960) for the onset of invalidating pain.

RESULTS

1. *Frequency and distribution to level of degenerated or ruptured discs verified by plane film and discography*

1055 lumbar discs have been examined. The distribution is seen in Fig. 1. According to the plane film there were in 555 (52.6%) discs signs of degeneration, but discography showed a rupture in 1024 (97%) discs. The discogram shows the following types: normal 31 (3%), early stage 464 (43.9%), late stage 560 (53.1%), partial rupture 520 (49.7%) and complete rupture 504 (47.7%). The distribution of level (indicated in % of number of examined discs per level) of plane film—and discographic findings is illustrated in Fig. 1.

2. *Discogram of discs which according to plane film are normal*

In 500 discs there were no signs of discs degeneration according to plane film. The distribution of level is seen in Fig. 2. The discogram in these discs shows the following types: normal 25 (5%), early stage 322 (64.2%), late stage 153 (30.2%), partial rupture 383 (76.6%) and complete rupture 92 (18.4%). The distribution of level (indicated in per cent of number of examined discs per level) of discographic findings is seen in Fig. 2.

3. *Discogram of discs which according to plane film are degenerated*

In 555 discs there were signs of degenerated discs according to plane film. The distribution of level is seen in Fig. 3. The discogram in these discs shows the following types: normal stage 6 (1.1%), early stage 142 (25.6%), late stage 407 (73.3%), partial rupture 137 (24.1%) and complete rupture 412 (74.8%). The distribution of level (indicated in

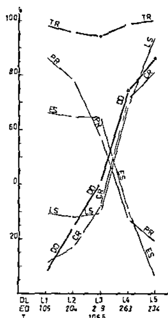


Fig 1

Distribution in percentage (%) of lumbar disc degeneration in relation to disc level (DL) Total (T) of 1055 examined discs (ED) DD = degenerated disc verified by plane film (o—o—o) TR = total number of ruptured discs verified by discography (+—+—+) Types of discograms (— — —) as early stage (ES) late stage (LS) partial rupture (PR) and complete rupture (CR)

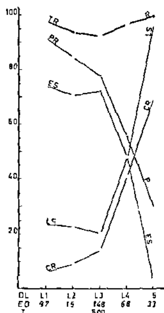


Fig 2

Distribution in percentage (%) of discographic findings in relation to disc level (DL) in lumbar discs which according to plane film lack signs of disc degeneration total (T) of 500 examined discs (ED) TR = total no of ruptured discs verified by discography (+—+—+) Types of discograms (— — —) as early stage (ES) late stage (LS) partial rupture (PR) and complete rupture (CR)

per cent of examined discs per level) of discographic findings is given in Fig 3

The six discs showing normal discograms only revealed slipping of the ventral surface on the plane film as a sign of disc degeneration

4 *Frequency and distribution to levels of pain producing ruptures verified by discography and its relation to degenerated discs verified by plane film*

In 1024 lumbar discs the discograms revealed ruptures and in 392 (38 3%) there were painproducing ruptures (PPR) The distribution of level (indicated in per cent of examined discs per level) of disc dege

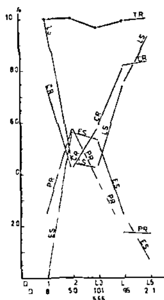


Fig 3

Distribution in percentage (%) of discographic finding in relation to disc level (DL) in lumbar discs which according to plane film show signs of disc degeneration total (T) of 555 examined discs (ED) TR = total no of ruptured discs verified by discography (+—+—+) Type of discograms (— — —) as early stage (ES) late stage (LS) partial rupture (PR) and complete rupture (CR)

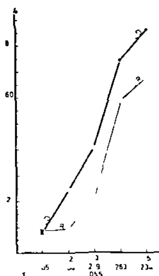


Fig 4

Distribution in percentage (%) of degenerated discs (DD) according to plane film (o—o—o) and pain provoking rupture (PPR) verified by discography (×—×—×) in relation to disc level (DL) Total (T) of 1055 examined discs (ED)

neration (according to plane film) and pain producing rupture are tabulated in Fig 4

Pain producing ruptures verified by discography which according to plane film show normal discs

Of the 500 normal discs according to plane film 89 (17 8 %) have pain producing ruptures according to discography These constitute 22 7% of all demonstrated pain producing ruptures The distribution of level (indicated in per cent of examined discs per level) of the 89 pain producing ruptures is given in Fig 5

In 19 cases all lumbar discs are normal according to the plane film

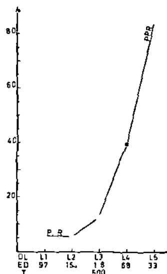


Fig 5

Distribution in percentage (%) of pain provoking ruptures (PPR) verified by discography (×—×—×) in relation to disc level (DL) in lumbar discs which according to plane film lack signs of disc degeneration total (T) of 500 examined discs (ED)

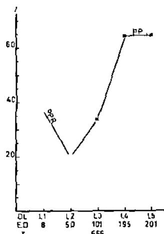


Fig 6

Distribution in percentage (%) of pain provoking ruptures (PPR) verified by discography (×—×—×) in relation to disc level (DL) in lumbar discs which according to plane film show signs of disc degeneration total (T) of 555 examined discs (ED)

In these cases discography revealed 26 pain producing ruptures in total 7 cases of which had multiple ruptures of that kind

6 *Pain producing ruptures verified by discography of discs which according to plane film are degenerated*

Of 555 degenerated discs according to plane film 303 (60 %) had pain producing ruptures according to discography The distribution of level (indicated in per cent of examined discs per level) of pain producing ruptures is given in Fig 6

DISCUSSION

Before beginning the discussion of the results of the investigation it should be pointed out that my series regarding the occurrence of discographically verified disc ruptures (97%) does not differ from other investigations (*Lindblom* 1950 *Sieber* 1952 *Friedman & Goldner* 1955) where the figure has been given as 79–96 per cent

My investigation shows that with plane film degeneration of the disc can only be revealed in approximately 50 per cent of the number of discs concerned. This verifies the fact that plane film is not reliable as a method of examination when disclosing degeneration of the discs —furthermore this has been proved at sections (*Friberg* 1947, *Friberg* & *Hirsch* 1950). According to *Walk* (1953) grave degenerative changes are usually found at discography in intervertebral discs which according to plane film show signs of discs degeneration. My examination shows that there is a similar course of the curves representing the occurrence of disc degeneration verified by plane film and grave degenerative changes (late stage and complete rupture) revealed by means of discography (Fig. 1). This points to the necessity of massive changes in the disc before changes occur which on the plane film are interpreted as disc degeneration.

It is not uncommon that the height of the lumbo-sacral disc is reduced on the plane film (*Hampton* & *Robinson* 1936) and according to *Knutsson* (1937) this change is of no clinical importance. *Williams* & *Fullenlove* (1956) believe that there can be no disc degeneration in the lumbo-sacral disc until its height is reduced to 50 per cent or more than the above lying disc. My investigation (Fig. 1) shows that according to discography there are degenerative changes in all lumbo-sacral discs but that plane film lacked signs of disc degeneration in 14 per cent (Fig. 1). The source of error in plane film could no doubt have been much greater here if I had determined the lumbo-sacral disc according to *Fullenlove*. My investigation (Fig. 4) also shows that it is more common with grave degenerated changes (late stage and complete rupture) in the lumbo-sacral disc. Consequently it must be expected that this disc will have a lowered height more often as compared with others. In view of this a lowered lumbo-sacral disc on a plane film must always be a sign of disc degeneration. Perhaps it may be considered remarkable that my series does not show one single normal lumbo-sacral disc but other examinations (*Friedman* & *Goldner* 1955) show similar conditions with respect to that level with a normal disc in 4 per cent only.

According to *Friberg* & *Hirsch* (1950) a normal disc on a plane film does not exclude grave degenerative changes. This has further been verified by discography (*Grassberger* & *Seyss* 1955, *Nordlander*, *Salen* & *Unander-Scharin* 1958). My investigation shows similar conditions and that this phenomenon is most usual in the two caudal discs (Fig. 2).

If there are any signs of disc degeneration on plane film the discogram will always show a rupture (*Lindblom* 1951 *Grassberger & Seyss* 1955 *Walk*, 1953) My investigation (Fig 3) shows similar conditions and that there are usually also grave degenerative changes (late stage and complete rupture) This is most pronounced in the two caudal discs My investigation furthermore shows that if on the plane film there is only slipping ventral surface the discogram may be normal in one or two cases

In series subjected to operation (*Malmros* 1942 *Wiberg* 1943 *Waris* 1948 *Rovig* 1949 *Bjorkesten* 1954 *Knutsson & Wiberg* 1958) lumbar herniated discs are usually to be found in the two bottom lumbar discs Disc ruptures giving symptoms in my series are located similarly (Fig 4) Investigations based upon plane film show that disc degeneration need not cause pain (*Bistrom* 1954 *McRae* 1956 *Lindholm & Pingoud*, 1957) My investigation shows that disc ruptures caused symptoms in fully 1/3 also there were asymptomatic ruptures in all levels however most common in discs with the most cranial position (Figs 1 and 4)

It is not uncommon that a herniated disc giving symptoms originates from a disc which according to plane film is normal (*Rovig* 1949 *Norlen* 1944 and others) and according to *Williams & Fullenlove* (1956) this occurs in 33 per cent My series shows symptoms from ruptured discs in fully 1/5 of normal discs as revealed in plane film and as a rule found in the two bottom discs (40–85%) (Fig 5)

Hirsch (1951) has pointed out that a degenerated disc demonstrated on plane film does not need to be the cause of pain My series shows that there are disc ruptures causing symptoms in 2/3 of the discs which according to plane film show signs of degeneration There is a certain variation with respect to level and the discs in a caudal location more often have disc ruptures giving symptoms as compared to other levels (Fig 6)

The investigation shows that plane film is a method of examination which no doubt has sources of error when it is a matter of revealing or excluding lumbar disc degeneration and consequently ruptures giving symptoms This is also the reason why correlation cannot be demonstrated between pain and disc degeneration in cases examined with plane film Papers have also been published (*Vara & Waris* 1952 *Brailsford* 1955) where plane film examination serves as a basis for conclusions regarding disc degeneration and existing pain In view of my results these investigations must lack scientific importance

As the sources of error in plane film are known with respect to disc degeneration and further that the film causes rather large doses of irradiation to the genes (*Larsson* 1958) there is reason to restrict the use of this examination. This is especially important as the examination tends to become one of the frequently used roentgenologic examinations (*Larsson* 1958). Of course plane film examination must be carried out if in connection with existing pain spondylitis or a tumour cannot be excluded (*Jelsma* 1944, *Burns & Young* 1947, *Tomey, Poppen & Hustley* 1950, *Vara & Waris* 1952, *Odell & Key* 1955 and *Fernstrom* 1956). But even in these diseases plane film examination is an unreliable method of examination (*Lachman & Whelan* 1936, *Sjoquist* 1942, *Eiselberg* 1952, *Bokstrom* 1953, *Fellander* 1955).

SUMMARY

Plane film and discography have been employed to examine 1055 lumbar discs in cases of low back pain and/or sciatica. The examination shows that plane film examination does not exclude sources of error as regards disclosure and exclusion of degenerated discs and, as a sequel, ruptures giving symptoms. It is then found that according to plane film normal disc does not exclude grave degenerative changes with ruptures giving symptoms, that according to plane film degenerated discs does not need to be the cause of pain and that a lowered lumbo-sacral disc always implies degeneration. Due to the results of the examination and because of the plane film examination causing rather severe irradiation damage to the genes, it is necessary to be careful not to use this examination for cases with low back pain and/or sciatica unless spondylitis or a tumour is suspected.

RÉSUMÉ

Le film plan et la discographie ont été utilisé pour examiner 1055 disques lombaires dans des cas de douleurs lombaires et/ou de sciatiques. L'enquête prouve que l'examen au film plan n'exclut pas les sources d'erreur en ce qui concerne la découverte et l'exclusion de disques dégénérés et, en tant que séquelles, les ruptures donnant des symptomes. Il a été constaté au moyen du film plan qu'un disque normal n'exclut pas de graves altérations dégeneratives avec ruptures donnant des symptomes, que des disques dégénérés ne causent pas forcément des douleurs et qu'un disque lombosacré assombri indique toujours une

degeneration Étant donné les résultats de cette enquête et du fait que l'examen au film plan peut présenter un grave danger d'irradiation pouvant influer sur les gènes il convient d'être très prudent et de ne pas l'utiliser dans les cas de douleurs lombaires et/ou de sciatiques à moins de soupçonner la présence d'une spondylite ou d'une tumeur

ZUSAMMENFASSUNG

Planigraphie und Diskographie wurden angewendet um 1055 Len denwirbelzwischenscheiben in Fällen von Lumbago und Ischias zu untersuchen Die Untersuchung zeigt dass die Planigraphie Fehler quellen hinsichtlich der Entdeckung und Ausschliessung von degene rierten Zwischenwirbelscheiben und folgenden symptomgebenden Scheibenbrüchen nicht ausschliesst Man fandt daher das eine gemäss der Planigraphie normale Zwischenwirbelscheibe schwere degenerative Veränderungen mit symptomverursachendem Bruch nicht ausschliesst dass ferner eine gemäss der Planigraphie als degeneriert zu bezeich nende Bandscheibe nicht Schmerzen hervorzurufen braucht und dass eine verschmälerte Zwischenscheibe immer eine Degeneration bedeutet Wegen der Ergebnisse dieser Untersuchung und da die Planigraphie ziemlich schwere Bestrahlungsschäden der Keimdrüsen verursacht er scheint es notwendig vorsichtig mit dieser Art der Untersuchung bei Lumbago und oder Ischias zu sein vorausgesetzt dass nicht der Ver dacht auf Spondylitis oder Tumor besteht

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FROM THE ORTHOPAEDIC CLINIC ST GÖRANS HOSPITAL STOCKHOLM
(HEAD MAC FELLANDER M D)

TUBERCULOUS OSTEITIS FOLLOWING B C G VACCINATION

By

MAC FELLANDER

Complications of B C G vaccination have been described by many Scandinavian authors Most complications appear at the site of vaccination and consist of specific reactions locally in the skin or regionally in the lymph nodes Four fatal cases of generalized spread of the tuberculous process have been published however (1 4 8 11) In all these 4 cases the main feature was generalized lymphadenitis In 1 of the cases multiple foci in the skeleton were found (*Thrap–Meyer* 1954 *Waaler & Oeding* 1954)

A further 5 cases with generalized spread have been reported and in 3 of them bone lesions were found A short account of these cases is of interest in connection with the present observations

One child who was vaccinated 4 weeks after birth developed 6 months later a lupus like lesion at the site of inoculation with regional adenitis Examination ? years after vaccination showed multiple bone lesions in the metatarsus the ulna and the vertebral column (*Imerslund & Jensen* 1954) The patient was in poor general condition but survived the disease after surgical treatment and chemotherapy

In a 7 month old child osteitis with sinus formation developed in the ulna 6 months after B C G vaccination The process healed after operation and chemotherapy (*Morkbak* 1954)

A 2 4 year old child who was vaccinated at the age of 3 days and again because of a negative tuberculin test 4 months later developed a fistulating tuberculous lesion in the talus which healed after operation and chemotherapy (*Haraldsson* 1959)

Horwitz & Meyer (1957) have published a survey of the complications of B C G vaccination in which they mention all cases published up to the present In all of them the diagnosis was verified by identification of bacterial type

Thus I have found 4 published cases of tuberculous osteitis in which bacilli of the B C G type were demonstrated. In 2 of them the patient had a solitary lesion and in 2 multiple lesions.

PRESENT INVESTIGATION

Tuberculous infection in children has declined strikingly in Sweden during the last few decades. As from 1951 data on the age distribution for newly discovered tuberculosis cases can be found in the annual report of the Central Tuberculosis Dispensaries, and it will be seen from Table 1 that there has been a marked decrease for children under 5 years of age in the 10 year period 1951–1960 as well. At the Orthopaedic Clinic, St Görans Hospital, which is a special department for bone and joint tuberculosis, on an average 1 child per year has over the same period of time been treated for newly discovered tuberculosis. The causes of this striking decrease in the incidence of tuberculosis in children are of course many, and one of them is probably the B C G vaccination scheme which to nearly 100 % covers all infants in the first few weeks of life.

TABLE 1

Cases of newly discovered tuberculosis in children under 5 years of age

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Number of registered tuberculosis cases in Sweden	218	[illegible]	[illegible]	65	4	39	[illegible]	[illegible]	14	14
Number of cases of bone and joint tuberculosis at St Görans Hospital	1	1	1	1	–	1	0	0	1	2

Even before the first cases of serious B C G complications were published we had begun to consider the question whether the few cases of bone tuberculosis in children could be caused by B C G. In the 10 year period 1951–1960 we had seen 10 such cases in children under 5 years of age. All had been B C G vaccinated in the first few weeks of life without any local complications. In none of them did X ray of the chest show any pathological changes. All of the 7 children that were tuberculin tested were found positive. Further data on these 10 cases are set out in chronological order in Table 2. In cases 5, 6 and 9, in which the lesion was localized to the sternum and the radius, the symptoms ap-

TABLE 2

Cases of tuberculous osteitis in children under 5 years of age during the period 1951–1960

Case	Age	Sex	Localization	Trauma	Histological examination	TB culture	Guinea pig	Pre-operative chemotherapy
1	1 1/12	♂	Distal end of right fibula	no	tuberculosis	negative	negative	–
	11/12	♂	Proximal end of left tibia	no	tuberculosis	–	negative	2 days
3	1	♂	Distal end of left ulna	no	tuberculosis	negative	negative	4 weeks
			Proximal end of left tibia		tuberculosis	negative	negative	4 months
			Distal end of left femur		tuberculosis	negative	negative	7 months
4	9/12	♀	Proximal end of left fibula	yes	tuberculosis	negative	–	7 days
5	4	♂	Distal end of left radius	yes fracture suspected	tuberculosis	negative	negative	4 months
6	3 8/12	♀	Distal part of sternum (substernal)	yes	tuberculosis	negative	negative	–
7	1	♀	Proximal end of right tibia	yes fracture suspected	tuberculosis	–	negative	3 weeks
8	1 4/12	♀	Right cuboid bone	no	tuberculosis	negative	negative	12 days
9	3	♀	Central part of sternum	yes	tuberculosis	negative	negative	–
10	1 2/12	♀	Distal end of right femur	no	tuberculosis	positive	negative	–

peared at 3 to 4 years of age In the other 7 children the disease ran a fairly similar course The onset occurred about 1 year after vaccination and in one of the cases the bone lesion was localized to the cuboid bone but in the others it was seated around the epiphyseal line in the long bones

In 5 of the cases one or several traumata were said to have been the factor that brought the symptoms into notice but these statements must of course be viewed with great caution In 2 cases however the trauma was so severe that a fracture was suspected at the hospital to which the child was first taken

All the children were treated by operation and chemotherapy The course was benign all the lesions healed and so far no disturbances in adjacent zones of growth have been noted At operation specimens were taken for histological examination cultivation of the tubercle bacillus and guinea pig tests In all the cases the diagnosis could be verified by histological examination Guinea pig tests were made in 9 cases and all were negative Tb cultures were made in 8 cases and were negative in all except for the last case in which the examination was positive and a strain with all the properties characteristic of the B C G type was identified A detailed description of the case will be given here

CASE REPORT

A girl born on April 1? 1959 to healthy parents was B C G vaccinated on the left thigh ? days after birth The vaccine did not differ in strength or otherwise from the generally used Swedish B C G vaccine Nor have any complications been reported in other children who were vaccinated at the same time

The girl developed no local reactions at the site of vaccination She was breast fed for 3 months and was in good health during the first year of life There is no known heredity or exposure to tuberculosis

When she was 14 months old diffuse symptoms referable to the right knee joint appeared with increasing swelling in the next few months At the age of 19 months he was admitted to a children s clinic Her temperature was normal F S R was normal and X ray of the chest showed no abnormalities A tuberculin test was positive X ray of the right knee joint showed a destruction in the distal end of the femur A proof puncture at the level of the destruction was made and yielded a small amount of thick yellow pus ordinary culture of the pus produced no bacterial growth

On the suspicion of tuberculosis she was transferred to this clinic on Nov 19 1960 On admission she had a normal temperature F S R by the micro method was 68 mm in an hour and her general condition was good On the left thigh there was a small mark after a Calmette vaccination without any reactive phenomena Around the lower part of the right thigh a diffuse swelling was seen and the range of movement in the knee joint was restricted by pain X ray showed a large cavity in

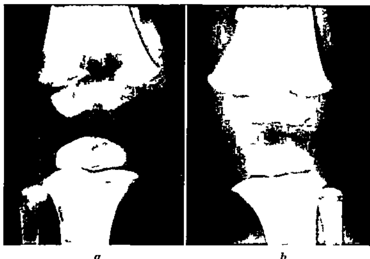


Fig 1a Radiograph before operation A large bone lesion centrally in the distal end of the femur

Fig 1b The healthy knee joint

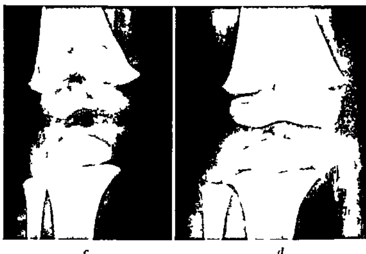


Fig 1c 4 weeks after evacuation of the cavity Ossification of the medial condyle of the femur has begun this indicates that it was not destroyed initially as possibly suggested by Fig 1a but only poorly developed because of the adjacent inflammatory process

Fig 1d 16 months after operation Bone structure is seen within the area of the old lesion which has decreased in size The medial condyle of the femur has now developed normally The epiphyseal line and the condyles seem to be developing normall

the end of the femur extending across the epiphyseal line into the epiphysis and in the centre of sequester like formation was seen (Figs 1 a and b)

Operation was performed on Nov 24 1960 when the child was 19½ months old without previous chemotherapy On the medial aspect of the knee a large para articular abscess was found which through a very narrow fistula at the level of the epiphyseal line communicated with the large bone cavit The posterior cortical wall of the cavity was very thin and there a hole was chiselled through which the cavity could be emptied of its content of pus and granulation tissue After local application of streptomycin the wound was closed by primary suture The material obtained at operation was examined histologically and bacteriologically

The histological examination showed epithelioid cell granulomas with central areas of caseous necrosis and numerous giant-cells of Langhans type At the periphery of the granulomas there were numerous plasma cells and a small amount of lymphocytes Acid fast rods were seen in the slides

At the bacteriological examination ordinary culture produced no growth Culture on Lowenstein medium yielded acid fast rods A guinea pig test was negative Identification of type was done at the Bacteriological Laboratory in Gothenburg and the following answer was obtained "The mycobacteria isolated from the patient are not virulent for guinea pigs (3 animals inoculated) The do not grow at 20 C or 45 C and are sensitive to PAS streptomycin and isoniazid In contrast to tubercle bacilli of the human type but similarly to bovine tubercle bacilli the bacteria are wholly sensitive in pentacyclic carbonic acid hydrazide Since the isolated mycobacteria are avirulent for guinea pigs and are of the bovine type they cannot be distinguished from B C G bacteria (*Arne Lind*)

The postoperative course was uncomplicated The operative wound healed by first intension She was immobilized in plaster for 2 months and treated with chemotherapeutic agents (streptomycin and isoniazid) over 11 months She was in hospital for 4½ months The subsequent clinical course was also uncomplicated The range of movement in the knee joint became normal soon after the removal of the plaster and she has remained symptom free Radiologically the cavity has gradually decreased and bony structure is visible (Figs 1c and d) It will also be seen in the radiograph that the medial condyle of the femur the ossification of which has been delayed is developing normally and up to the present there have been no signs indicating growth inhibition despite the fact that part of the epiphyseal line has probably been destroyed

DISCUSSION

Out of the 10 children under 5 years of age who in the past 10 year period were treated for bone and joint tuberculosis 5 had bone lesions localized to the epiphyseal line of the knee joint (cases 2 3 4 7 and 10) In these children as well as in 1 with a lesion in the distal end of the fibula (case 1) and in 1 with a lesion in the cuboid bone (case 8) i e 7 children in all the disease ran a similar course with onset at about 1 year after B C G vaccination In 1 of these 7 cases B C G bacilli were demonstrated In 3 the onset of the disease did not occur until 3 to 4 years after vaccination 2 of these (cases 5 and 9) in which the

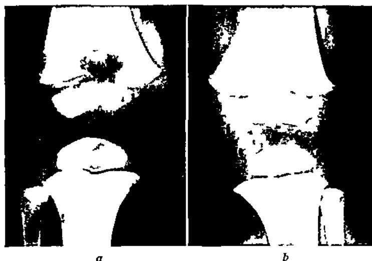


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DISCUSSION

Out of the 10 children under 5 years of age who in the past 10 year period were treated for bone and joint tuberculosis, 5 had bone lesions localized to the epiphyseal line of the knee joint (cases 2, 3, 4, 7 and 10). In these children, as well as in 1 with a lesion in the distal end of the fibula (case 1) and in 1 with a lesion in the cuboid bone (case 8), i.e. 7 children in all, the disease ran a similar course with onset at about 1 year after B.C.G. vaccination. In 1 of these 7 cases B.C.G. bacilli were demonstrated. In 3 the onset of the disease did not occur until 3 to 4 years after vaccination, 2 of these (cases 5 and 9) in which the

seat of the lesion was the distal end of the radius and the centre of the sternum respectively, did not differ essentially in any other respect from the rest. One child (case 6) however had a substernal abscess which at operation was interpreted as osteitis secondary to soft tissue affection, possibly in a lymph node.

The development of tuberculous bone lesions is a result of haematogenous spread. That such a spread of B C G can occur has been shown by *Gormsen* (1956) in an interesting study comprising histological examinations in connection with autopsies of B C G vaccinated human beings. He was able to demonstrate the presence of epithelioid cell granulomas locally at the site of vaccination and in the regional lymph nodes as well as in several internal organs but not in bone marrow. He does not state to what extent bone was examined however. These granulomas did not show the picture typical of tuberculosis with formation of tubercle nodules but had a strong resemblance to the histological picture that was found in the fatal cases after B C G vaccination. *Gormsen* draws the conclusion that at least 2 to 3 years after vaccination signs of generalized haematogenous spread can be found although there has been no manifest disease.

Ustvedt (1956) after an analysis of the 4 fatal cases discusses the question of immunity and summarizes that the laboratory procedures could not throw any light on the question why generalized fatal disease should develop. He also points out that it is difficult to explain the atypical histological picture which to some extent resembles the findings in non reactive generalized tuberculosis (*sepsis tuberculosis acutissima*).

In all my cases described here we are concerned with benign tuberculosis with in one case multiple and in the others solitary bone lesions all of which healed after operative treatment combined with chemotherapy. The histological picture in the case in which B C G was demonstrated was characterized by the presence of numerous plasma cells diffusely without any very marked accumulation around the tuberculous foci. In view of this finding which to some extent differs from what is usually observed in human tuberculosis the histological findings in the other cases reported here were carefully examined. This analysis revealed in some cases a similar diffuse plasma cell infiltration, in others a more or less marked accumulation around caseous lesions and epithelioid cell tubercles.[1]

[1] The histological examination was carried out by *Åke C H Lindgren*

I cannot find any satisfactory explanation of the causation of the lesions There were no local reactions at the site of vaccination The information about traumata in 5 cases and in some of them distinct injuries is remarkable however Trauma and tuberculosis are an interesting constellation The relationship is repudiated by several experimental workers but some clinical observations are such that the importance of the trauma in the manifestation of a tuberculous lesion cannot be wholly denied (*Konshegg Rich*) It is of course difficult to judge the significance of the trauma when the patients are infants as in the cases under discussion but since the symptoms appeared in close association with severe traumata we can hardly exclude the possibility that the trauma activated a latent lesion which according to *Gormsen s* investigations is always present

It is of course of the greatest interest that these B C G infections should be established Unfortunately identification of the type is made difficult by the fact that B C G is a bovine strain of low virulence and is not easily differentiated from other bovine strains In 6 of my cases the patients had been in some other hospital where chemotherapy had been given on the basis of the histological diagnosis before the cultures had been made (Table 2) It is possible that this is the reason why we obtained so many negative cultures The chemotherapy had in some cases lasted for a short time only but may nevertheless have been sufficient to enable the concentration in the specimens to inhibit bacterial growth Our own routine is to avoid if possible chemotherapy before operations in order to established a confident bacteriological diagnosis The main object is to be able to distinguish between septic and tuberculous infections before adequate therapy is instituted If a B C G infection which is much more difficult to diagnose bacteriologically is suspected it is still more necessary to follow this routine

This report is intended as a contribution to the current discussion on the safety of B C G vaccination and the question whether mass vaccination is still justified (*Wallgren* 1956) In most of these 10 cases of tuberculous osteitis the process can be suspected to be of the B C G type even though B C G was demonstrated in only 1 case In all the cases the course was benign The localization close to and the partial destruction of the growth zones of the long bones in these infants may under unfavourable conditions lead to considerable growth disturbances Fortunately no such disturbances have so far occured in the cases reported here

SUMMARY

Tuberculous osteitis in the lower end of the femur developed in a 14 month old child who had been B C G vaccinated 2 days after birth Tubercle bacilli identical with the B C G strain were recovered

Over the 10 year period 1951–1960 a further 9 children under 5 years of age were treated for tuberculous osteitis which was verified histologically In most of these cases the course of the disease was fairly similar to that in the first named case All were B C G vaccinated in the first few weeks of life and in 6 of the children the symptoms appeared approximately 1 year after the vaccination Identification of bacterial type could not be made since the cultures were negative

In all the cases the course was benign and the process healed after operation combined with chemotherapy One of the patients had multiple the others solitary bone lesions Because of its localization to the proximity of the growth zones of the long bones the disease must be regarded as serious despite its otherwise benign course So far however no disturbances of the growth have occurred in the cases reported here

The importance of trauma in the manifestation of the bone lesions is discussed

RESUME

Une osteite tuberculeuse de la partie inferieure du femur s est developpee chez un enfant age de 14 mois qui avait eté vacciné par le B C G deux jours apres la naissance Des bacilles tuberculeux identiques a la lignee du B C G ont eté recueillis

Dans la periode decennale 1951–1960 9 autres enfants de moins de 5 ans ont eté soignes pour une ostéite tuberculeuse assez similaire au premier cas mentionne Tous avaient eté vaccines par le B C G dans les premieres semaines de la vie et chez 6 de ces enfants les symptomes se sont manifestes environ un an apres la vaccination L identification du type bacterien n a pu etre faite les cultures ayant ete negatives

Dans tous ces cas le cours de la maladie fut benin et la guerison intervint apres une operation combinee de chemotherapie Un des malades avait de multiples lesions osseuses les autres une lésion solitaire Par suite de sa localisation a proximite de la zone de croissance des os longs la maladie doit etre consideree comme etant grave malgré son cours benin Jusqu ici aucun trouble de la croissance ne s est cependant manifesté dans les cas rapportes ici

Il est discuté de l importance que peut présenter un trauma dans la manifestation de lesions osseuses

ZUSAMMENFASSUNG

Tuberkulöse Osteitis entwickelte sich im unteren Ende des Femurs bei einem 14 Monate alten Kind, das 2 Tage nach der Geburt B.C.G. vakziniert worden war. Tuberkelbazillen, die identisch mit denen der B.C.G. Vakzine waren, wurden nachgewiesen.

Während der 10 Jahrsperiode 1951–1960 wurden weiterhin 9 Kinder unter 5 Jahren wegen tuberkulöser Osteitis, die derjenigen des erster wähnten Falles ziehmlich ähnlich war, behandelt. Alle waren während der ersten Lebenswochen B.C.G. vakziniert worden und bei 6 der Kinder traten Symptome ungefähr ein Jahr nach der Vakzinierung auf. Die Bakterientype konnte nicht festgestellt werden, da die Kulturen negativ waren.

In allen Fällen war der Verlauf gutartig und der Prozess heilte nach Operation kombiniert mit Chemotherapie aus. Einer der Patienten hatte vielfache, die anderen nur einen einzigen Knochenherd. Wegen des Sitzes in der Nähe der Wachstumszonen der langen Rohrenknochen muss die Erkrankung trotz ihres im übrigen gutartigen Verlaufes als ernsthaft angesehen werden. Vorläufig sind jedoch keine Wachstum störungen in den hier berichteten Fällen aufgetreten.

Die Bedeutung des Traumas in der Lokalisation der Knochenherde wird besprochen.

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (HEAD PROF SÖLVE WELIN) ALLMÄNNA SJUKHUSET MALMÖ AND THE PAEDIATRIC CLINIC CENTRAL HOSPITAL FALKÖPING (HEAD DR KURT PALMÉN)

SEASONAL VARIATION OF BIRTH DATES OF INFANTS WITH CONGENITAL DISLOCATION OF THE HIP

By

LARS ANDRÉN and KURT PALMÉN

Some years ago *Nagura* (1955) and *Pap* (1956) reported a considerable seasonal variation in the time of birth of infants with congenital dislocation of the hip in Japan and Hungary respectively

Of *Nagura* s series 43 per cent of the 1306 newborns with congenital dislocation of the hip were born in December February the corresponding figures for *Pap* s series being 42 per cent of 217 Recently *Record & Edwards* (1958) described a series of 186 cases from Birmingham in which 35 per cent of the children were born in December February

In a series from Leipzig covering the years 1928–1957 and consisting of 4345 cases *Uibe* (1959) found a similar though less marked seasonal variation in his series 28 per cent were born in December February but he did not take into consideration the normal seasonal variation of the total birth rate

Pap reported that this seasonal variation was also found for children in whom the disease was diagnosed at birth but he did not give the number of newborns on which he based this conclusion and this number can hardly have been large for his entire series consistered of only 217 cases In the publications by the other above mentioned authors nothing is said about the newborns at all

Since statistical data are available on the frequency of congenital dislocation of the hip covering the major part of Sweden (*Palmen* 1961) diagnosed partly at birth partly later it was considered worthwhile checking whether any seasonal variation could be demonstrated and if so whether there was any difference between the frequency curve of those cases diagnosed at birth and those diagnosed later and whether the shape of the curve varied with sex

MATERIAL

The material was divided into 3 series. Series A consisted of 1313 children (1118 females, 195 males) with dislocation of the hip treated at the departments of orthopaedics in Sweden during 1945 to 1960. *These cases were not diagnosed at birth but mostly after 1 year of age.*

Series B was made up of 816 cases (661 female, 155 males) diagnosed at birth during the years 1953 to 1960.

Series C consisted of the boys in both groups (350 cases).

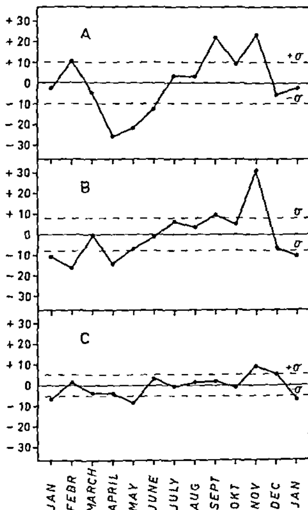


Fig 1

Graphic demonstration of differences between observed and expected values for the individual months of the year in the three series.

Random deviation calculated as $= \sqrt{n \times 1/12 \times 11/12}$

TABLE 1

Survey of observed and expected values for the months of the year in the three series

Series		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	
A	Observed	106	117	118	97	100	[illegible]	113	107	127	114	1[illegible]0	95	— 1313
	Expected	10[illegible].2	106.5	1[illegible]2.5	122.0	121.7	111.[illegible]	109.5	103.9	10[illegible]	104.5	[illegible]6.5	100.[illegible]	— 1312.8
	Diff	—[illegible]	+10.5	—4.5	—25.0	[illegible]1.7	—1[illegible]	+3.5	+3.1	+[illegible]1.8	+9.5	+23.5	—5.2	
B	Observed	57	50	76	6[illegible]	[illegible]9	[illegible]8	74	68	75	70	91	5[illegible]	— 816
	Expected	67.2	[illegible]0.2	76.1	76.4	75.6	[illegible]9.1	[illegible]8.1	[illegible]4.5	[illegible]5.4	[illegible]5.0	[illegible]0.0	[illegible]	— 815.9
	Diff	10.[illegible]	—10.2	—0.1	—14.4	—[illegible].6	—1.1	+[illegible].1	+[illegible].5	+[illegible].6	+5.0	+31.0	—6.3	
C	Observed	2[illegible]	30	9	29	[illegible]4	33	[illegible]	[illegible]	[illegible]1	[illegible]7	[illegible]5	3[illegible]	— 350
	Expected	28.8	[illegible]8.4	3[illegible].7	3[illegible].8	3[illegible].4	[illegible]3.6	[illegible]1.2	27.7	[illegible]8.0	27.[illegible]	[illegible]5.7	26.7	— 3[illegible]
	Diff	—6.8	+1.6	—3.7	—3.8	—8.4	+[illegible].4	—0.2	+1.[illegible]	+[illegible].0	—0.[illegible]	+9.[illegible]	+5.[illegible]	

A ± 10.0   B ± 7.[illegible]   C ± [illegible]

RESULTS

The frequency curve for the patients according to date of birth thus showed a clear seasonal fluctuation with the crest of the wave in September-November and the trough in March-May, i.e. about 3 months earlier than in the other series referred to above. The shape of the curve for those cases diagnosed at birth was also the same as that for cases diagnosed later, usually after 1 year. The curve for the boys did not differ from that for the entire material.

DISCUSSION

Nagura ascribed this seasonal variation to differences in the heaviness of the clothing: in summer the children's clothing is lighter than in winter and therefore affords greater freedom of movement of the limbs, which facilitates spontaneous reduction of the dislocation. This view is shared by *Record & Edwards* (1958) who say: "The most likely explanation is that infants born in winter, particularly during cold weather, have to endure heavier clothing and cot coverings. This is likely to cause severe restriction of limb movements and prevent the thighs from assuming the natural position of flexion, abduction and external rotation, which is similar to the position adopted in the conventional treatment of the deformity."

This explanation is, however, less satisfactory because the frequency in those children in whom the disease was discovered at birth, i.e. before restriction of limb movements by clothing, showed the same seasonal variation. The difference in the heaviness of the clothing may, however, accentuate the existing seasonal variation.

It has been shown that dislocation of the hip is one of the manifestations of increased instability of the pelvis of the same nature as that in mothers during pregnancy and similar to that which can be induced in experimental animals by administration of oestrogen or relaxin (*Andrén* 1960). Evidence has also been produced to the effect that the breakdown of maternal and placental oestrogens and exogenous oestradiol is decreased in newborns with congenital dislocation of the hip (*Andrén & Borglin* 1961).

These observations make it likely that it is the seasonal influences, climatic or alimentary, on the hormonal interrelationship that are responsible for the seasonal variation in the birth dates of infants with congenital dislocation of the hip.

SUMMARY

A seasonal variation of dates of birth of infants with congenital dislocation of the hip was found for 866 cases diagnosed at birth and 1736 cases diagnosed later. The variation was the same for both groups and for both sexes.

RÉSUMÉ

Dans une série de 866 cas de dislocation congenitale de la hanche constatée à la naissance et de 1736 cas diagnostiques plus tard, on a observé par rapport aux dates de naissances des enfants une variation saisonnière qui est la même pour les deux groupes et les deux sexes.

ZUSAMMENFASSUNG

Eine an die Jahreszeit gebundene Variation der Geburtsdaten von Kindern mit kongenitaler Hüftverrenkung wurde bei 866 Fällen, die zur Zeit der Geburt diagnostiziert wurden und bei 1736 Fällen, die später erkannt wurden, gefunden.

Die Variation war die gleiche in beiden Gruppen und für beide Geschlechter.

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Fig 1 a
Guide and bone screws

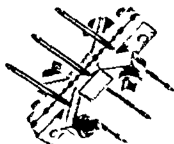


Fig 1 b
By means of the guide the screws can be driven into the bone parallel to and at a certain distance from one another

Among its main disadvantages were mentioned soft tissue infection at the site of the pins, ring sequestra and osteomyelitis. Other drawbacks were pain and difficulties in obtaining and maintaining reduction and inadequate immobilization (*Johnson & Stowall* [12] 1950)

The latest additional instrumentarium for transfixation was designed by *Raoul Hoffmann* (9). In 1938 he described for the first time his method which he had devised simultaneously with and independently of *Stader* and *Roger Anderson* and which he called Osteotaxis from

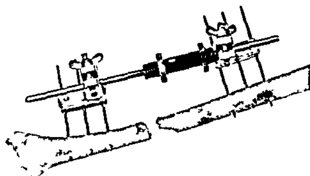


Fig 2 a
The instruments are applied on an experimentally fractured autopsy specimen of the tibia The parallel bone screws in each set are fastened together with a grip

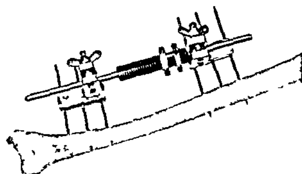


Fig 2 b
The same specimen as in Fig 2 a The fracture has been reduced exactly and fixed firmly by compression achieved by tightening the left nut on the coupling bar

[illegible] I arrange) Since then he has successively improved the instruments and in several papers (9 10 11) he has given detailed descriptions of the technique of osteotaxis A brief account of the instruments and the technique will be given here for further particulars the reader is referred to *Hoffmann* s original works [1]

1 A short descriptive survey in English is available from the manufacturer of the instrumentarium Jaques Frères Geneva and from the retailers AB Kifa Stockholm

Transfixation is done with special screws made of steel alloyed with chromium and nickel 18/8 (Fig. 1). Through a special piercing model called "guide" (Fig. 1) 3–5 screws are driven into the bone above and below the fracture. A grip is applied to each set of screws and the sets are fastened together with a coupling bar which has a device for compression of the fracture (Fig. 2). To avoid electrical tension the grips are covered with a non-conducting material (resofil). The Hoffmann apparatus can be regarded as a perfect instrumentarium for transfixation. Osteotaxis has come into use notably in the French speaking countries: in France, Switzerland and Belgium. In Sweden it was introduced by *Orell* (17). In the English speaking countries it is probably fairly unknown. Some case-reports have been published (3, 4, 5, 6, 7, 14, 15, 18, 21, 22), but no survey of a collected clinical material can be found in the literature. According to *Hoffmann* osteotaxis is indicated mainly in open fractures but also in closed fractures where reduction and fixation are difficult, in multiple fractures, fractures with delayed union and pseudarthrosis.

OWN MATERIAL

At the Orthopaedic Clinic, the St. Göran's Hospital, Stockholm, 49 fractures in 47 patients were treated by this method over the years 1952–1960. It should be emphasized here that they were cases of difficult fractures in which treatment by usual methods had failed or had from the beginning been rendered difficult by adverse circumstances.

The following data will illustrate this point:

26 of the fractures were open. In 5 there were skin injuries which required some form of plastic operation. 10 patients had multiple fractures, 4 of them in the same limb. 2 patients had nerve injuries and 1 patient had arterial damage in association with the fracture. 11 patients had earlier undergone operation for a pseudarthrosis, 8 of them once, 2 twice and 1 ten times.

2 patients had two different fractures that were treated by osteotaxis, one with an open fracture of the tibia of both legs, one with pseudarthrosis of the femur of one leg and the tibia of the other leg.

Sex and age. Of the 47 patients 13 were women and 34 men. Their ages ranged from 17 to 78 years.

Localization of the fractures and pseudarthrosis. The distribution according to site is shown in *Table 1*, in which fractures and pseudarthroses are also set out separately. Cases of delayed union and cases

of non union are listed together It may be difficult to draw the line between delayed union and non union and I have therefore found it most expedient to group them together in the table but in the text I have tried to analyze the cases with delayed union separately

TABLE 1
Distribution of fracture and non union according to site

Localisation	No of cases	Fracture	Non union
Humerus	4	2	2
Forearm	6	1	5
Femur	11	3	8
Tibia	28	9	19
Total	49	15	34

Of the 15 cases listed as fractures 5 were primarily treated by osteotaxis The other 10 were not treated until after intervals that varied between 4 and 42 days with a mean of 21 days other methods of fixation having failed

TABLE 2
Results of osteotaxis distributed according to site of fracture and non union

Localisation	No of cases	Healed	Not healed
Humerus	4	3 (3)	1
Forearm	6	5 (2)	1
Femur	11	8 (4)	3
Tibia	28	24 (13)	4
Total	49	40 (22)	9

Figures in parentheses Healed with normal function

Among the 34 cases listed as non union 28 are cases of true pseudarthrosis in which the patients were admitted for treatment 5 months to 12 years after the accident the mean being 1 year and 8 months The other 6 can be designated as cases of delayed union mostly combined with malposition of the fracture They were treated 2 to 3 months after the accident

RESULTS

All the patients were followed up by clinical and radiographic examination after a period of observation varying between 1 year and

6½ years. The therapeutic results are given in *Tables 2 and 3*. The figures in parentheses show the number of patients in whom the fractures healed *without giving any clinical symptoms and whose joint* function is now normal or so slightly reduced as to be of no practical importance. Accordingly, healing failed to occur in 9 out of 49 cases, namely for 2 fractures and 7 pseudarthroses. Further data on the results are given in *Table 4*, in which fracture and non union are listed separately. Among the forearm pseudarthroses 1 only is recorded as healed without functional impairment. A further 2 patients are very little handicapped, one despite complete loss of pronation and supination, the other one with pronation and supination to half the normal range and slight reduction of movement of the wrist as a result of simultaneous dislocation of the semilunar bone. The fracture of the femur recorded as healed with impaired function has, however, healed with much better function than the concurrent fracture of the femur of the other leg, which was treated by open reduction, osteosynthesis and immobilization in plaster. Many patients with lower leg pseudarthrosis had on admission considerable knee-stiffness after previous prolonged immobilization in plaster. This explains the great number of cases of healing with impaired function. However, it may be mentioned that 3 of the patients whose fractures healed without impairment of function had on admission considerable stiffness after previous prolonged plaster fixation for 7½ months, 1½ years and 1¾ years respectively.

TABLE 3

Results of osteotaxis for fracture and non union

	No. of cases	Healed	Not healed
Fracture	15	13	2
Non union	34	27	7
Total	49	40	9

Osteotaxis without complementary operation on the pseudarthrosis. 10 patients with non union or delayed union were treated by osteotaxis only, 5 on the lower leg, 4 on the femur and 1 on the forearm. Healing occurred in all of them after fixation for periods varying between 3 and 8 months (*Table 5*). In 3 of these cases the result can be designated as delayed union, the fracture healed after fixation for 3½, 5 and 5 months respectively, and the course of healing did not differ from that

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in cases of true pseudarthrosis As regards the interval between injury and osteotaxis its length varies within the whole of this group from 2½ to 13½ months (*Table 6*) In 3 cases of femoral pseudarthrosis treated 9, 13½ and 19 months respectively after the primary injury healing occurred with osteotaxis only and one of these patients had an infected pseudarthrosis For the lower leg pseudarthroses the longest interval between injury and treatment was 9½ months In 2 patients who were primarily treated by osteotaxis only this procedure was found to be insufficient and without removing the instruments it was completed by operation on the pseudarthrosis These 2 cases are included in the following account

TABLE 4
Details of results shown in Tables 2 and 3

		No of cases	Healed	Not healed
Humerus	fracture	2	2 (2)	–
	non union	2	1 (1)	1
Forearm	fracture	1	1 (1)	–
	non union	5	4 (1)	1
Femur	fracture	3	2 (1)	1
	non union	8	6 (3)	2
Tibia	fracture	9	8 (8)	1
	non union	19	16 (5)	3
Total		49	40 (22)	9

TABLE 5
Results and period of fixation by osteotaxis in cases of delayed union and non union with and without surgical intervention on the pseudarthrosis

Surgical intervention	No of cases	Healed	Not healed	Time of fixation in months
Without	10	10	–	3 8
With	24	17	7	3½ 9

In the healed group

Osteotaxis with complementary operation on the pseudarthrosis In 24 cases osteotaxis was combined with some form of operation for non union two being only osteotomy of the fibula the rest operation on the pseudarthrosis itself The distribution of the pseudarthrosis according to site was as follows 14 in the lower leg 4 in the femur 4 in the fore arm and 2 in the humerus In 17 cases healing occurred after a period

of fixation varying between 3½ and 9 months (*Table 5*). This group includes 3 cases with delayed union and they healed after fixation for 4½, 4½ and 8¼ months respectively. In the whole of this group the interval between injury and treatment ranged from 2 months to 12 years (*Table 6*).

TABLE 6

Results and interval between injury and osteotaxis in cases of delayed union and non-union with and without surgical intervention on the pseudarthrosis

Surgical intervention	No. of cases	Healed	Not healed	Interval injury—osteotaxis
Without	10	10	–	2½–13½ m
With	24	17	7	2 m–12 yr

TABLE 7

Period of fixation by osteotaxis

	No. of	Time in months
Healed fractures	13	2½–7 (4½)
Not healed fractures	2	4½–13
Healed non-union	27	3–9 (5½)
Not healed non-uion	7	3–6 (4)
Total	49	2½–13 (5)

The length of fixation with the Hoffmann apparatus is shown in Table 7: it varied between 2½ and 13 months. It should be noted that the period of fixation in the group with healing is not identical with the time required for the healing of the fracture. For additional security the apparatus was retained longer than necessary. The routine procedure was as follows. After the clinical consolidation had been tested and X-ray assessed as showing satisfactory healing, the patient was allowed to be up and about for a short time with the bone screws left in place but the coupling bars disconnected. If, after about a week, the patient had no pain and the signs of consolidation were good, the bone screws were removed. It happened that the patients themselves wanted to keep the instruments fixed on longer than necessary for the sake of safety, which suggests that the fixation is well tolerated.

Complications. In 28 of the 49 treated fractures the course was uncomplicated. In 8 cases slight infection arose at the site of one or several screws, and in a further 8 cases more marked infection occurred with

out giving rise to manifest osteitis Only one patient had long lasting suppuration from a few screw tracks granulation tissue was curetted out but no bone sequestra were found and the fistulas healed very soon after the revision As a rule the small skin defects at the screw tracks healed very quickly after the removal of the instruments even when infection had been present At the follow up examination none of the patients complained of discomfort at the sites of the removed screws Nor were there any complaints relating to the quite inconspicuous scars

In 5 cases the bone screws worked loose so that the treatment had to be discontinued In 1 of these cases, a patient with an ulnar pseudarthrosis the osteotaxis procedure was repeated 3½ months after the screws had come loose and the pseudarthrosis healed

Analysis of failures

9 (18%) of the 49 treated fractures did not heal

In 1 case of ulnar pseudarthrosis the period of fixation was too short 2½ months The instruments were removed after misinterpretation of the radiograph Subsequent checkings by X ray in oblique views showed clearly that the pseudarthrosis had not healed It was later treated successfully by onlay grafting

One patient with an infected pseudarthrosis in the upper part of the humerus had marked osteoporosis which caused loosening of the screws so that the treatment had to be discontinued

3 out of 11 femoral fractures did not heal In one of these cases the screws had incorrectly been inserted on the front of the thigh through the quadriceps muscle which probably was the reason why they come loose Healing occurred later on after operation on the pseudarthrosis and internal fixation with a blade plate In the second case a femoral pseudarthrosis the treatment had to be discontinued after 5 4 months because of infection in the screw tracks The fracture healed after operation on the pseudarthrosis and medullary nailing In the third case the patient had a comminuted fracture of the femur with injury of the sciatic nerve The fracture was first treated by skeletal traction but owing to malposition of the fracture osteotaxis was performed but the bone ends could not be brought into contact with one another The treatment was discontinued after 13 months of fixation The fracture healed later after operation on the pseudarthrosis

Among the cases of tibial fractures treatment failed in 4 A four day old fracture with unsatisfactory position was treated by osteotaxis which was discontinued after 4½ months because of non healing and slight screw track infection The fracture healed after operation on the pseudarthrosis In a man with a 1? year old pseudarthrosis for which he had previously undergone 10 operations healing was not obtained by osteotaxis combined with inlay grafting The screws came loose after 3 months largely because the patient who was under the effect of ethylism refused to stay in the hospital and follow the instructions Later on the pseudarthrosis necessitated amputation In one case of non union with a large defect and infection admitted for treatment 2 years and 8 months after the injury healing was not



Fig 3

Case 1 — a Pseudarthrosis of the humerus b The pseudarthrosis has been resected Fixation by osteotaxis c 5½ months later healing has occurred d 6 years later

obtained by fixation for 6 months The screws came loose and later on amputation was performed One patient with an infected tibial pseudarthrosis was treated by osteotaxis and osteotomy of the fibula but a fracture line remained right through an excessive callus formation Because of insignificant symptoms further treatment was not necessary

From this analysis it is seen that many of the unsuccessful results occurred in difficult cases One failure was due to a technical error and another to misinterpretation of the radiograph taken to check the healing

CASE REPORT

To illustrate the advantages of the method and to demonstrate the difficult type of the treated fractures some representative cases will be reported

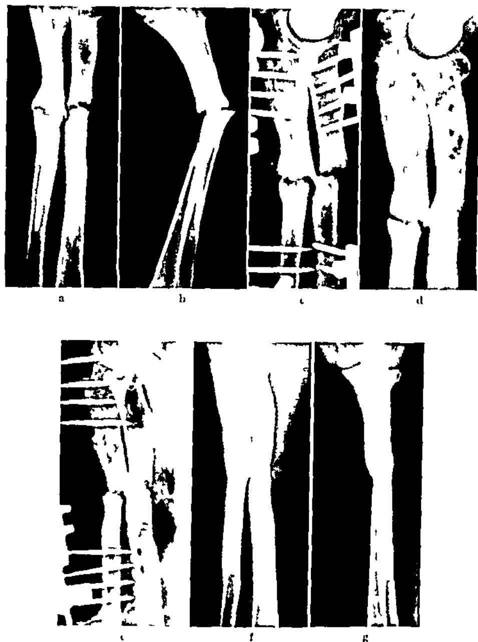
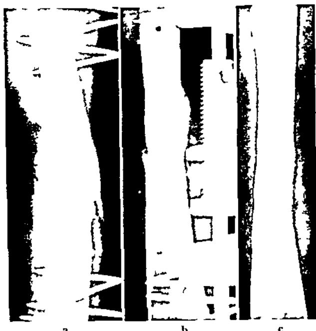


Fig 3

Case 2 —a and b Pseudarthrosis of the radius and ulna c Fixation by osteotaxis d Radial fracture healed ulnar pseudarthrosis persists e Second osteotaxis on the ulna combined with inlay grafting 10 months after the primary osteotaxis treatment f and g 2 years later



a b c

Fig 5

Case 3 — a Pseudarthrosis of the femur Two sets of bone screws applied at different levels b Coupling bar attached fracture reduced in exact position and compression established c 10½ months later

Case 1 A 49 year old man with a fracture of the humerus primarily treated by medullary nailing and later twice by operation for pseudarthrosis. Osteotaxis combined with resection of the pseudarthrosis 2 years and 9 months after injury Period of fixation 5¼ months Patient resumed work as a foreman 6 weeks after operation wearing the osteotaxis instruments Healing with normal function of the joint No symptoms (Fig 3)

Case 2 A 28 year old man with open fracture of the radius and ulna Primary treatment by Lane's plate on the radius and medullary nailing of the ulna Later on operation for pseudarthrosis without effect Osteotaxis 4 years after injury Period of fixation 5½ months Healing of the radial but not of the ulnar fracture Second osteotaxis on the ulna combined with inlay grafting Period of fixation 3 months and 3 weeks Healing with pronation and supination reduced by 2/3 of normal range No symptoms (Fig 4)

Case 3 A 35 year old woman with a femoral fracture treated earlier by medullary nailing and operation for pseudarthrosis without effect Osteotaxis combined with splitting of the pseudarthrosis 16 months after injury Period of fixation 6 months and 3 weeks Bed rest for 8 days only Hospital care for 1 month Patient able to walk about freely wearing the appliances Healing with normal function of the joint (Fig 5)

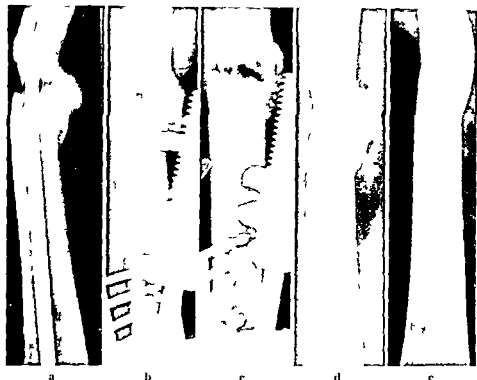


Fig 6

Case 4 —a Pseudarthrosis of femur 9 months after primary treatment by medullary nailing b Fixation b osteotaxis without surgical intervention on the pseudarthrosis c Compression established d 4 months later clinical and radiographic healing e 3 years later

Case 4 A 42 year old woman with severe injuries one leg amputated through the thigh on the other leg a femoral fracture and severe skin damage Medullary nailing resulted in pseudarthrosis with marked malposition Osteotaxis 9 months after the accident Period of fixation 4 months Treatment carried through despite the poor condition of the skin with extensive grafts and infection in some screw tracks Fracture healed with slightly reduced movement in the knee joint function otherwise normal (Fig 6)

Case 5 A 5? year old woman with fracture of the femoral neck and the tibia of the same leg To enable reduction of the femoral neck fracture on the traction table the lower leg fracture had to be firmly fixed Osteotaxis on the day after the accident Simultaneous closed reduction and osteosynthesis of the femoral neck fracture The lower leg fracture fixed by the instruments for 3½ months Healing with normal joint function (Fig 7)

Case 6 A ?0 year old man with an open lower leg fracture primarily treated with Lane's plate Later on operation for pseudarthrosis by onlay grafting Infection intercurred His leg had been immobilized in plaster for 1½ years and he



Fig 7

Case 5 —Fracture f femoral neck and tibia of the same leg After transfixation of the tibia reduction and osteosynthesis of the femoral neck fracture could be carried out immediately a and b Anteroposterior and lateral views of transfixed tibial fracture c and d Anteroposterior and lateral views 1 year after the accident (fracture healed in 3½ months)

had considerable stiffness of the knee and ankle joints Osteotaxis 1 year and 9 months after the injury Osteitic bone removed and replaced by bone-chips The course was uncomplicated Period of fixation 5 months Healing with normal joint function (Fig 8)

DISCUSSION AND CONCLUSIONS

Hoffmann s method for fixation of fractures enables good reduction fixation and compression and allows free movements in adjacent joints These are exactly the most important factors in the ideal healing of


a b c d

Fig 8

Case 6—a Infected pseudarthrosis of the tibia b Fixation by osteotaxis after removal of osteitic bone and grafting c 6 weeks after operation the bonegrafts have been partly transformed d 6 months after operation the grafts are completely transformed the fracture has healed

fractures with optimal function Our experiences in this respect have been good The patients can be immobilized early Even patients with lower leg fractures are able to be ambulant soon after operation and in *favourable cases very early weight bearing can be allowed*

In the justified criticism of transfixation methods described earlier the risk of infection has been emphasized in particular The question whether it is a true bacterial infection or a matter of electrolytic irritation has been discussed Hoffmann s instrumentarium reduces the last named factor because the screws are made of highest quality steel and isolated from one another in a fully satisfactory way The risk of bacterial infection should be taken into consideration but can be

reduced by an exact technique and meticulous care of the skin [1] In the series of patients presented here screw track infection was no great problem only in 1 case did long lasting suppuration occur Apart from this the screw tracks healed very quickly after the instruments had been removed In no case did osteitis develop

According to *Hoffmann* and several of his followers open fractures are the main indication for osteotaxis We have no experience with this application of the method since very few patients with acute open fractures were admitted to this clinic during the period of study As far as we can judge from our experiences in other cases however osteotaxis should be the ideal method in severe open comminuted fractures where other methods of fixation cannot maintain a good position of the bone ends provided of course that the surrounding skin allows trans fixation

Our experiences relate to patients with difficult fractures and pseud arthroses in many cases primarily treated by other methods and accordingly to a selected material of difficult cases This fact must be considered in the assessment of the results Looking at the pseudar throsis cases only healing failed to occur in 7 cases out of 34 or in 20% For the sake of comparison may be mentioned the large series of pseud arthrosis cases recently published from the Campbell Clinic at Memphis in the U S A (*Boyd et al* [2]) in which the incidence of non healing after the primary operation on the pseudarthrosis was 12% Our results appear particularly favourable if one considers not only the healing of the fractures but also the joint function which is much better after osteotaxis than after prolonged immobilization in plaster

As regards the treatment of pseudarthrosis a question of interest is whether or not it is necessary to combine osteotaxis with surgical inter vention In most of our cases we combined osteotaxis with some form of operation on the pseudarthrosis either primarily or after some time when we did not notice any tendency to healing In 10 cases however the fractures healed with osteotaxis only Among these were 3 that would more properly be designated as delayed union but also some pseudarthroses even one that was infected The question whether to operate or not on the pseudarthrosis must be decided from case to case depending upon the appearance of the pseudarthrosis and the mechani cal possibilities for exact fixation

1 A suitable protective dressing is obtained by spraying the skin with Nobecutan ® (Bofors Sweden) which forms a thin protective plastic coating and applying a Telfa bandage (Kendall Chicago) whose plastic-coated side adheres to the skin

On the basis of nine years experience with osteotaxis the following conclusions are drawn

The method is not suitable for routine use especially in a surgical department with great accumulation of acute cases In special departments where those in charge of the case have time to follow carefully the technical instructions osteotaxis is an excellent complement to the usual methods of fracture treatment

Osteotaxis is particularly expedient for difficult fractures for open fractures where it can be difficult to achieve a good position and fixation by other measures for multiple fractures and for pseudarthroses where it is desirable to avoid too prolonged immobilization of adjacent joints

All the long bones are suitable for osteotaxis perhaps the tibia in particular on which the instruments are easily applied and which is the commonest site of difficult fractures

The method involves no risks and is strikingly well tolerated by the patients who often spontaneously state that they prefer osteotaxis to immobilization in plaster

SUMMARY

A selected series of patients with difficult fractures and pseudarthrosis of the long bones were treated by Hoffmann s method of osteotaxis

The material consists of 49 fractures of which 40 healed The results are assessed as very favourable in view of the degree of severity of the cases Very good joint function was obtained because the method allows early mobilization

No serious complications occurred In no case did osteitis develop in the screw tracks To avoid such inflammation it is essential that the technical instruction be followed and that meticulous care be taken of the skin

Osteotaxis is not suitable as a routine method but it is recommended in difficult cases of fractures and non union

RESUME

Une série selectionnee de malades avec fractures compliqués et pseudarthrose des os longs ont ete traités par la méthode de l ostéotaxis de Hoffmann

Le materiel d observation comprend 49 fractures dont 40 se soudèrent Les resultats sont considérés comme tres favorables en raison du degré

de gravite de ces cas Une tres bonne fonction de l articulation a ete obtenue parce que la methode permet une mobilite precoce

Aucune complication serieuse n a ete constatee Dans aucun cas il ne s est developpe d osteite a l endroit de la vis Afin d eviter l inflammation il est essentiel de suivre strictement les instructions techniques et de prendre un soin meticuleux de la peau

L osteotaxis ne convient pas comme methode de routine mais elle est recommandee dans les cas de fractures compliquees et de pseudarthrose

ZUSAMMENFASSUNG

Eine ausgewählte Reihenfolge von Patienten mit schwierigen Bruchen und Pseudarthrosen der langen Rohrenknochen wurde mittels Hoffmanns Methode der Osteotaxis behandelt

Das Material besteht aus 49 Bruchen von denen 40 heilten Die Ergebnisse werden wenn man die Schwere der Falle in Betracht zieht als sehr gunstig angesehen Ausgezeichnete Gelenksfunktion wurde erzielt da die Methode fruhzeitige Mobilisierung gestattet

Keinerlei ernsthafte Komplikationen traten ein In keinem Falle entstandt Osteitis in den Schraubenbohrungen Es ist wesentlich dass man der technischen Anweisung genau Folge leistet und dass man die Haut sorgfaltig behandlet um derlei Entzundungen zu vermeiden

Osteotaxis eignet sich nicht als eine Durchschnittsmethode kann aber in Fallen von schwierigen Bruchen oder Pseudarthrosen anbefehlt werden

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FOOT DROP IN LEPROSY AND ITS SURGICAL CORRECTION

By

JOHN G ANDERSEN

In the management of preventible and correctible deformities due to lepra drop foot occupies an important place The nature of these two departments have prevented any kind of survey of the total and relative incidence in the various types of lepra *Hemerijckx* (1959) reported a detailed survey from 8 associated clinics in S India He found in a group of 2337 patients 3 cases of bilateral and 59 cases of unilateral drop foot This is an overall incidence of 2 5 per cent

The pathology of this deformity has received considerable interest in these departments The important points in this context will be briefly mentioned A full discussion of this is outside the scope of this paper As a rule foot drop is due to paralysis of the lateral popliteal nerve just above the point where it winds round the neck of the fibula Previously it was thought that sooner or later all the muscles of the anterior and lateral compartments would become paralysed A certain amount of evidence admittedly preliminary is coming forward to suggest that we are dealing with two distinct patterns of paralysis complete lateral popliteal paralysis and incomplete lateral popliteal paralysis In the first type all the muscles of the anterior and lateral compartments are paralysed In the second type only the muscles of the anterior compartment are paralysed A certain number of cases will present themselves for reconstructive surgery with a "partial pattern of paralysis with only some of the muscles in these compartments paralysed We consider that such patterns indicate a process towards one of the stable patterns of paralysis or a recovering paralysis Another group will present more complex patterns of paralysis involving some muscles outside the lateral and anterior compartments as

well These irregular patterns of paralysis are considered due to one of the following factors 1) a concomitant post polio paralysis 2) a biological variant mainly found in the lepromatous and dimorphous cases with widespread nerve involvement or 3) a particular site of neural damage with no reference to any pattern as occasionally found in the tuberculoid cases

Of paramount importance is the fact that in the majority of cases the tibialis posterior muscle is active and suitable for transfer This is the rationale behind the standardized procedures it has been possible to develop

It deserves underlining that when a muscle becomes paralysed due to leprosy and when the pathological process has run its course the involved muscle is either completely paralysed or completely normal This is in strict opposition to post polio paralysis

Possible ways of correcting foot drop

Foot drop can be corrected in several ways 1) It has been impossible to find any references in the available literature but it can be heard expressed off the record that at least in Western women a drop foot need not be corrected since it is so well suited to a high heeled shoe This is not only too defeatist but distinctly wrong 2) The wearing of some mechanical device to maintain the foot in the desired position of dorsiflexion peroneus straps spring shoes etc Such devices undoubtedly have their place in the management of extreme paralysis They may also be of value in cases of partial patterns of paralysis where it is as yet uncertain what the final pattern of paralysis will be or where chances of neural recovery are still present They might be acceptable as permanent fixtures in certain communities but in the majority of the countries where lepra is prevalent they are definitely unacceptable for social and economic reasons 3) *Corrective surgery* of the skeletal structures of the foot mainly arthrodesis of the Lambrinudi type In cases of extreme paralysis this may be the only rational therapy but it should be considered a last resort for two reasons it is a major procedure fraught with danger esp in lepra where tarsal disorganisation is a fairly frequent and extremely distressing condition and the liability of the anterior joint capsule to stretch postoperatively will frequently undo any achievement of the operation and will indeed leave the foot in a worse condition 4) Transfer of a suitable muscle to achieve the desired dorsiflexion As pointed out above the tibialis

posterior muscle is active and suitable for transfer in the majority of cases of paralysis due to lepra Over a number of years various methods of tibialis posterior transfer have been used in these departments

This paper will present an evaluation of some of these methods It will also attempt a comprehensive presentation of the problems involved in foot drop in lepra

Literature Review

The use of the tibialis posterior muscle as a dorsiflexor of the foot goes back to *Ober* s report on 1933 It is now a widely accepted method In 1956 *Hodges* reported on the use of a Lambrinudi type of triple arthrodesis in 15 cases of foot drop due to lepra A 4 months follow up showed satisfactory results in all cases 2 patients seen 15 months after surgery showed good results Our reasons for not accepting this as a standard procedure have been stated In 1957 *Fritsche & Brand* reported on the correction of drop foot in lepra using tibialis posterior transfer with a tendon to bone insertion either via the interosseous or the circumtibial route They recommended high tension on the transferred muscle with the foot at right angle position with slack tendon in full dorsiflexion They found the circumtibial route slightly better than the interosseous Other related techniques were mentioned A detailed review of clawing of the toes was given Triple arthrodesis of Ryerson type was recommended for tarsal neuropathy In 1957 *Gunn & Molesworth* reported on 56 cases of foot drop due to leprosy repaired by tibialis posterior transfer by circumtibial or interosseous route They demanded as preoperative conditions a complete lateral popliteal paralysis a reasonable passive dorsiflexion of the ankle and a strong tibialis posterior muscle They obtained 49 cases with satisfactory results They recommended tendon suture with the foot in dorsiflexion In 1959 *Selvapandian & Brand* gave a preliminary report on 39 cases of foot drop due to leprosy operated on by tibialis posterior transfer by circumtibial or interosseous route with a tendon to bone insertion Their results corresponded closely with those obtained by *Gunn & Molesworth* Their findings indicated a definite superiority of the circumtibial route The biological behaviour of tendon grafts and tendon transfers and also of the response to surgical trauma have been dealt with recently by *Brand* The problems of the neurological patterns in leprosy were dealt with by the author in 1961



Fig 2
Normal



Fig 3
Broomstick Y



Fig 4
Peroneus Y

Fig 2 shows in diagrammatic outline the arrangement of the tendons on the front of the ankle in the non operated normal foot

Fig 3 shows the arrangement of the tendons after a broomstick Y method of tibialis posterior transfer

Fig 4 shows the arrangement of the tendons after a peroneus Y method of tibialis posterior transfer

The following points should receive particular attention

1) The pattern of paralysis esp the suitability of the tibialis posterior muscle for transfer and partial patterns of paralysis

2) Duration of paralysis

3) Passive mobility of the ankle joint The drop foot usually assumes an equino varus position In a number of cases contracture of the posterior structures supervenes Although the triceps surae muscle is the chief culprit all the structures on the posterior aspect of the leg participate This deformity is better styled heel cord contracture than tendo Achillis contracture Based on clinical experience the author has defined heel cord contracture as the condition where passive dorsi flexion of the ankle to 70 or less is not possible keeping the knee straight and using no undue force

4) Skeletal malalignment and tarsal instability A point that is easily overlooked is the tibial displacement of the subtaloid joint either as a true angulating varus position or as a parallelaxic displacement with or without angulating varus A fixed deformity can render an otherwise successful operation valueless An unstable deformity likewise jeopardizes the result of a tendon transfer As a rule it is better to correct

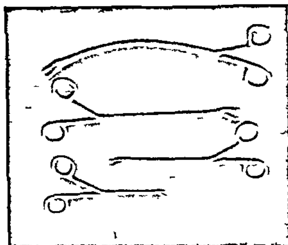


Fig 5

shows four varieties of the bluntnosed tendon tunneller designed by the author with open jaws No 1 is a curved tunneller designed for tibialis posterior transfer total length 35 cm No 2 and no 3 are straight tunnellers resp 30 and 20 cm long They are particularly useful in tendon transfers round the upper extremity No 4 is a slender tendon tunneller 15 cm long particularly useful for tendon transfers round the fingers and the eye

They are being manufactured by the Indian Sterilizer Company Madras

such deformities before tendon transfer is undertaken Heel cord contracture and claw toes can often be corrected simultaneously with tendon transfer for drop foot

5) Loss of tissue either due to true absorbtion or to incidental traumas should be recorded as should be scarring of the foot Both may have an important bearing on the choice of method and on the final result

6) Pathological stiffness of joints either fibrous or osseous ankylosis has an important bearing on the final result

7) Previous surgery may have an important influence on the choice of method and on the final result

Choice of method

Certain general points will here be considered

1) After transfer of the tibialis posterior muscle its tendon must be fixed either to the skeletal structures on the dorsum of the foot preferably the middle cuneiform bone or to the tendons on the extensor

side of the foot Both methods can produce good results Clinical experience in these two departments has led us to consider a number of points pro et contra Unfortunately the available material does not lend itself to a thorough analysis of these points

In favour of tendon to bone insertion are the following points

a) The absence of any sutures in the course of the gliding tendon means less chance of adhesions with reduction in active movement

b) Since only one tendon is transferred it is a relatively quick method

Against tendon to bone insertion are the following points

a) Interference with bone and periosteum will in certain cases produce an unsightly and troublesome swelling

b) Accidental infection even of low virulence may have a disastrous effect on the foot particularly if it penetrates into bone which is more likely to occur if the tendon is inserted into an osseous tunnel

c) Interference with the skeletal structures may trigger off neuropathy of the foot even in the absence of gross infection

d) Insertion of a tendon into bone of actually or potentially poor quality may not produce reliable anchorage

e) The frequently employed pull out wires through the sole of the foot are a source of trouble when fitting shoes It should be considered an axiom in surgery on anaesthetic feet that no incision may occur on the weight bearing surface

In favour of tendon to tendon insertion are the following points

a) Less than perfect balancing of the foot with only one guy rope as in transfer of the tibialis posterior tendon to the dorsum of the foot will tend to produce a progressive rotatory dorsiflexion with disastrous result to the gait A tendon to tendon insertion with one guy rope to either side of the foot will be more laterally stable unless the balancing is so defective that weight bearing forces the foot off balance In such case it is either a gross error of preoperative assessment or an equally gross technical error

b) Tendon to tendon insertion to the natural points of insertion might be expected to produce a more physiological function

c) In the methods of tendon to tendon insertion where one guy rope is inserted proximal to and the other distal to the transtarsal joint this

BROOMSTICK Y
TIBIALIS POSTERIOR TRANSFER—CIRCUMTIBIAL ROUTE

Postoperative Assessment

P sit on of r t	M l ll high stepping	No m l	
70			
70– 80			
80– 90		1	
90–100	1	8	
100 110	2	[illegible]	
110–120			
120–			
Total	3	11	(14)
Active Dorsiflexion			
70			
70– 80		5	
80– 90	2	3	
90–100	1	3	
100 110			
110–120			
120–			
Total	3	11	(14)
Range			
0– 10		1	
10 20	3	4	
20– 30		4	
30		2	
Total	3	11	(14)

Postoperative Deformities		*Overall Results*	
Tarsal deformity	1	Excellent	4
Claw toes	2	Good	7
Drop toes	1	Fair	3
		Poor	0

Total no. of cases 14

PERONEUS V

TIBIALIS POSTERIOR TRANSFER—CIRCUMTIBIAL ROUTE

Postoperative Assessment

Position of rest	Mild high stepping	Normal	
70			
70– 80			
80– 90		5	
90–100		3	
100–110	2		
110–120			
120–			
Total	2	8	(10)

Active Dorsiflexion

70		1	
70– 80		6	
80– 90	1	1	
90–100	1		
100–110			
110–120			
120–			
Total	2	8	(10)

Range

0– 10			
10– 20	1	4	
20– 30	1	3	
30–		1	
Total	2	8	(10)

Postoperative Deformities

Tarsal deformity	
Claw Toes	2
Drop Toes	1

Overall Results

Excellent	2
Good	6
Fair	2
Poor	

Total no. of cases 10

TENDON TO BONE
TIBIALIS POSTERIOR TRANSFER—INTEROSSEOUS ROUTE

Postoperative Assessment

Position of rest	High stepping	Mild high stepping	Normal
70			
70-80			
80-90			
90-100		3	12
100-110	3	10	6
110-120		2	
120-			
Total	3	15	18 (36)

Active Dorsiflexion

70			1
70-80		1	6
80-90	1	8	6
90-100	1	4	4
100-110	1	2	1
110-120			
120			
Total	3	15	18 (36)

Range

0-10			
10-20	2	6	1
20-30		7	13
30	1	2	4
Total	3	15	18 (36)

Postoperative Deformities		*Overall Results*	
Tarsal deformity	9	Excellent	4
Claw toes	11	Good	18
Drop toes	5	Fair	10
		Poor	4

Total no. of cases 36

TENDON TO BONE
TIBIALIS POSTERIOR TRANSFER—CIRCUMTIBIAL ROUTE

Postoperative Assessment

Position of rest	High stepping	Mild high stepping	Normal
70			
70– 80			
80– 90			5
90–100		6	17
100–110	1	8	6
110–120	1	3	
120–		1	
Total	2	18	28 (48)
Active Dorsiflexion			
70			
70– 80			8
80– 90		7	19
90–100	1	9	1
100–110		2	
110–120	1		
120–			
Total	2	18	28 (48)
Range			
0– 10			
10– 20	2	3	11
20– 30		13	9
30–		2	8
Total	2	18	28 (48)

Postoperative Deformities

Tarsal deformity	18
Claw toes	7
Drop toes	9

Overall Results

Excellent	12
Good	19
Fair	15
Poor	2

Total no. of cases 48

joint might be expected to remain more stable than where the insertions are all proximal to the joint (This applies mainly to the choice between the "peroneus Y and the broomstick Y methods)

d) In the methods where the toe extensors are incorporated in the insertion drop toes can be corrected simultaneously

2) The tendon of the tibialis posterior can be brought to the dorsum of the foot by two routes the interosseous or the circumtibial route Both are capable of producing good results although the author prefers the circumtibial subcutaneous route partly because it is technically easier particularly when a specially designed bluntnosed tendon tunneller is used and partly because more adhesions are likely to form when the tendon passes the tough interosseous membrane In cases where a narrow interosseous space is found the tendon may be strangulated

3) Attempts have been made to pass the transferred tendons circumtibially deep to the extensor retinaculum at the ankle in order to avoid troublesome bowstringing In all cases tough adhesions formed It should be recorded that bowstringing at the ankle has rarely been a source of trouble in this series

4) The doctrine of the Y This expression is being introduced to emphasise certain well known but easily forgotten principles of tendon transfer A transferred tendon that moves in a straight line or in a smooth mildly curved line is more likely to obtain a good gliding function than its opposite number moving in angulating irregular curves A transferred tendon moving in a single trunk from origin to insertion is superior to a branching tendon Branching tendon transfers are permissible under the following conditions The branching must take place in tissue where the formation of gliding mechanism is easily obtained The angle between the branches must be as acute as possible (in other words a tendon Y is superior to a tendon T) The point of the Y must be proximal since it otherwise would prevent the active contraction of the motor muscle Conversely the angle between the branches may be a factor in the early days of reeducation in preventing the strong triceps surae from pulling the weaker and operatively weakened tibialis posterior into an undesired position of plantar flexion The deviation of the branches from the motor tendon must be identical Where two or more tendons are joined together only the active motor tendon should be permitted to continue its course proximal to the junction since the excursion of the motor tendon otherwise will be hampered by the reserve Y This of course only holds true in the gliding course of a tendon

5) Tension of the transferred muscle Accurate grading of the initial and final strength of any transferred muscle is a tricky procedure The *points to consider are a) The required strength to counteract success*fully the newly acquired antagonists which may be stronger than the original ones b) The original range of the transferred muscle compared with the ideal range in the new position c) The physiological loss of strenght of any muscle when transferred as compared with the expected hypertrophy after reeducation d) The unavoidable loss of strength due to alteration of the angle between the contractile muscle fibres and the transmitting tendon fibres

Since the desired function is a simple one clean dorsiflexion at the ankle with the deliberate sacrifice of the more complex pronating supinating movements the problem can be simplified to preservation of the greatest possible amount of inherent strength to act in a range and with a placement of the range where the tibialis posterior in counterbalance with its newly acquired antagonists the triceps surae and the toe flexors can be expected to secure adequate stable dorsiflexion of the foot to allow a normal gait

The practical consequence of this is that the foot must be placed at an angle of dorsiflexion during operation and that the transferred tendon must be secured there under high tension Because of the phenomenon called drop of range the transferred tendon must be sutured under high tension at an angle of clean dorsiflexion of the ankle joint 10 degrees more than the desired postoperative dorsiflexion In order to allow healing under relaxed conditions the foot is immobilised in plaster of Paris under higher dorsiflexion than for the tendon suture In the majority of cases the foot can be expected to achieve an active dorsiflexion to 10 degrees short of the position of tendon suture (Preoperative passive dorsiflexion with straight knee 65 tendon suture at 70 immobilisation at 65 expected active dorsiflexion 80) It is not advisable to overdo the dorsiflexion of the ankle joint by passive flexion of the knee The result will be undue pressure between the food and the plaster cast

When the plaster cast is removed the foot will assume an angle of dorsiflexion about 10 degrees below the angle of initial immobilisation Any movement discernible at that time will be in the nature of active plantar flexion and a passive spring back As the range improves under physiotherapy the major part will develop from an increased pull of the antagonists and a pull back increasingly so by active muscle contraction of the transferred muscle

If heel cord contracture is present surgical correction is usually resorted to simultaneously with the foot drop correction The routine method is a Z plasty of the tendo Achillis Measurements during actual surgery indicate that the gain is one degree of dorsiflexion for every mm of lengthening

Pre and postoperative physiotherapy

Selection of the proper method assessment of expected postoperative results and actual results should be carefully recorded

Regular preoperative training is essential in order to obtain the best result from any method Although this is usually carried out in a relatively independent department of physiotherapy the closest possible co operation with the surgeon is recommended

When the decision has been taken that a particular foot is ready for surgery a short period of training is instituted The essential feature is to call the attention of the patient to the active play of the tibialis posterior muscle and training in its independent voluntary function This is done by placing the patient sitting with the paralysed foot over the opposite knee with the insted pointing up He is instructed to lift the forefoot Most patients will quickly learn this Attention to the skin with oil massage and wax bath has a definite place

After surgery the patient returns to the ward with the foot in a plaster cast below the knee incorporating a toe guard The author prefers to leave the toes open for inspection on the guard After a few days in bed with elevated foot a rocking device is incorporated and the patient is ambulated

Earlier this plaster cast was left intact for 6 weeks Since the introduction of the tendon to tendon insertion methods it is not considered necessary to immobilise the foot for more than 4 weeks

At the end of 4 weeks the plaster cast is removed and the posterior half of the bivalved cast is reapplied as a non weight bearing splint which is worn constantly outside training periods for the next 10 to 14 days The sutures are removed and unless some failure in union is evident active physiotherapy is instituted The first phase is active use of the transferred muscle with gravity as an assisting force This is done by placing the patient on his belly with the knee flexed at right angles Later active use of the transferred muscle with gravity eliminated is instituted with the patient sitting with the operated leg crossed over the opposite knee Still later active use against gravity is encou

ranged with the foot hanging down The final phase is weight bearing exercises first as rocking and balancing exercises between bars later as walking between bars and finally as free walk The whole time the patient is carefully instructed to use the transferred muscle in its full range even if he could get by with much less effort Active plantar flexion is only encouraged in the very last stages when the patient is confident in free walk Three to four weeks are the usual period of postoperative physiotherapy after which the patient is discharged with instructions to return later for follow up studies and final evaluation As the patient gains confidence in the daily use of the transferred muscle the careful deliberate overuse is changed into a more normal gait

Since this work is being done in close cooperation with an ulcer prevention programme no patient is permitted to walk until suitable light shoes are available This however is outside the scope of this paper

This work was started as a pioneer work with no clear concept of all the factors involved The personel and the methods of record keeping have changed during this period For these reasons the available data on many of the cases are not complete in view of present understanding of the problems

The majority of the cases have been operated on by one of four methods 1) tendon to bone insertion by the interosseous method 2) tendon to bone insertion by the circumtibial method 3) tendon to tendon insertion by the circumtibial method (peroneus Y) and 4) tendon to tendon insertion by the circumtibial method (broomstick Y) A follow up study of these four methods will be presented Other methods employed have all been used in so small numbers that a statistical analysis is not possible

Irrespective of the particular method employed three points should receive attention A perfectly aseptic technique is imperative The surgical anaesthesia employed is important particularly in respect of the tension of the transferred muscle For more than 12 months a lytic cocktail of chlorpromazine and pethidine has been used routinely This has been very satisfactory The tensions mentioned in this paper refer to this method Careful atraumatic tissue technique is extremely important This relates not only to handling of the tendons but also to skin incisions that should not override tendon junctions or the gliding course of the transferred tendons (*Brand* 1961)

Tendon to bone insertion methods

These are well known techniques The point of insertion is selected to secure a clean dorsiflexion In most cases the middle cuneiform bone is chosen A tunnel is prepared into the bone and the tendon is inserted into this Frequently a pull out wire is used through the sole of the foot

Thangaraj from Purulia in 1959 reported the use of interosseous transfer of the tibialis posterior to be inserted into the tibialis anterior the extensor hallucis and the extensor digitorum longus high in the leg He achieved good results although only in a small range This method obviously violates the doctrine of the Y It also invites crippling adhesions to the tough interosseus membrane Two other tendon to tendon insertion methods were therefore introduced almost simultaneously

The peroneus Y method

employs a circumtibial subcutaneous transfer of the tibialis posterior to the insertion of the tibialis anterior The tendon of the peroneus longus is divided high in the leg and withdrawn to the foot from where it is transferred subcutaneously across the ankle to be inserted into the tibialis posterior tendon at an acute angle at the point where it winds round the border of the tibia The foot is placed in dorsiflexion and the tendons are secured under equal and high tension The main advantage of this method is its relative simplicity and the use of good solid tendons Its main disadvantage is the lack of tendon insertions distal to the transtarsal joint When this joint is stabilised with active tendons on the flexor side and only tenodesis on the extensor side hypermobility and disorganisation may occure here

The broomstick Y method

was originally introduced by *Verghese & Andersen* It employed transfer of the tibialis posterior as in the peroneus Y method but instead of the tendon of the peroneus longus the extensor digitorum longus was used The extensor hallucis longus tendon was tenodised to the insertion of the tibialis anterior This has later been changed by the author to include transfer of both the extensor digitorum longus and the extensor hallucis longus to the point of the transferred tendon of the tibialis posterior where it winds round the border of the tibia The tendons are secured under equal high tension with the foot in dorsiflexion Attempts have been made to include the peroneus longus tendon in

the broomstick. This has no real advantage. On the other hand it adds one more tendon to be secured under high and accurate tension. The main advantage of this method is the insertion of tendons both distal and proximal to the transtarsal joint with more stability of this joint. It permits correction of concomitant claw toes. On theoretical grounds it would seem that the better leverage in the broomstick Y method permits better correction of mobile varus inversion deformities.

Both of these methods employ two guy ropes to stabilise the foot. This calls for meticulous attention to the diversion of the branches from the motor tendon and to the equality of the tension. It will frequently be found advantageous to place the foot in slight valgus eversion during tendon suture. This will compensate for the inevitable lateral shift of the tendon junction and consequent slackening of the lateral guy rope.

Attempts have been made to avoid incisions on the dorsum of the foot by a circumtibial transfer of the tibialis posterior across the anterior compartment, interweaving on its way with the tendons of the tibialis anterior, extensor hallucis longus and extensor digitorum longus, all of which are brought forward through windows in the deep fascia. These attempts have failed to produce good results, as is to be expected, since they violate the doctrine of the Y, and also employ a motor tendon transferred in an undulating course through tissue with a poor tendency to formation of gliding mechanism.

Postoperative presence of drop toes or claw toes, although they have no direct bearing on the operative method employed, detract from the final result, since they constitute a hazard to the foot.

The available material does not permit a complete evaluation of tarsal deformities. In any case their presence postoperatively will detract from the final result. Presence of preoperative fixed tarsal deformities is an indication for triple arthrodesis prior to tendon transfer. Passively reducable but stable tarsal deformities can be corrected by tendon transfer provided due attention is paid to correct alignment and tension. Their presence postoperatively is therefore a failure of the surgeon to obtain the best possible result from the employed method. Preoperative unstable tarsal deformities cannot be expected to be corrected by tendon transfer. They constitute an indication for triple arthrodesis prior to tendon transfer. The present material does not permit a thorough evaluation of these points. It is hoped that this will be possible later.

This material does not permit an analysis of the relation between

preoperative passive dorsiflexion (presence of heel cord contracture) and the achieved postoperative active dorsiflexion It is hoped that this will be possible later

A comparison between the two tendon to bone insertion methods indicates a superiority favouring the circumtibial route This is probably due to crippling adhesions in the interosseous space

In a few cases the tendon suture was done with the tendon slack with the foot in dorsiflexion The results are reflected in the few cases of postoperative highstepping gait found in the tendon to bone insertion methods

The author s contention that the tendon suture must be performed under 10 degrees more dorsiflexion than the expected active postoperative dorsiflexion is based on a series of cases that have not been included in the present study

The material does not permit a study of the relation between tendon to bone insertion and tarsal neuropathy It has been found in some cases but no analysis will be attempted

The position of rest seems to have some influence on the gait It should be 90 degrees or less in order to secure an easy gait with no high stepping as the foot is carried forward The angle of active dorsiflexion seems to have greater influence on the gait It must be less than 90 degrees in order to secure a normal gait In a few cases normal gait has been recorded in the presence of insufficient active dorsiflexion These cases all belong to the early group It is reasonable to suggest that the criteria for grading the postoperative results have become stricter over the years It is tempting to attempt correction for this discrepancy It has however not been done Since all the oldest cases belong to the tendon to bone insertion methods this theoretical correction would tend to emphasise the superiority of the tendon to tendon insertion methods

The range of active movement from extreme dorsiflexion to extreme plantar flexion will be found expressed in the active range A high range does not seem to have any influence on the gait provided the range has the correct placement

The number of cases on record does not permit any definite evaluation between the tendon to bone insertion methods and the tendon to tendon insertions methods There appears to be some tendency towards better results from the tendon to tendon insertion methods The small material does suggest a slight superiority of the broomstick Y method over the peroneus Y method

SUMMARY

The author presents a study of 108 cases of drop foot in leprosy operated by tibialis posterior transfer. Four distinctive variations of this method are described including two previously undescribed methods of tendon to tendon insertion. A review of the problems relative to foot drop in leprosy is presented.

ZUSAMMENFASSUNG

Der Verfasser berichtet über eine Untersuchung von 108 Fällen von Lepra Fallfuss, die mittels Transplantation des m. tibialis posterior *behandelt wurden. Vier unterschiedliche Variationen dieser Methode* einschliesslich zweier vorher nicht veroffentlichter Methoden der Vereinigung von Sehne zu Sehne werden beschrieben.

RESUME

L'auteur presente l'etude de 108 cas de « drop foot » chez des lepreux operes par transfert du jambier posterieur. Quatre variations distinctes de cette methode sont décrites, y compris deux methodes d'insertion de tendon à tendon qui n'ont pas eté decrites auparavant. Les problémes relatifs au « drop foot » de la lepre sont passés en revue.

ACKNOWLEDGEMENTS

The author wishes to record his sincere gratitude to friends and colleagues from the Thursday morning clinic, particularly Mr. *P. W. Brand*, F.R.C.S., for his inspiring and critical guidance, Mr. *M. Furness*, records and assessment officer, whose deep knowledge of the problems of reconstructive surgery has been invaluable in this work, and Mr. *D. Ward*, senior physiotherapist, to whose enthusiastic cooperation much of the advance in physiotherapy owes its origin.

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ULTRASONIC TREATMENT OF EPICONDYLITIS HUMERI

By

OLE MUNE and KJELD THORSETH

Epicondylitis humeri is an aseptic inflammation of the tendons of caput commune extensorum (lat.) or flexorum (med.). Occurence of lateral localization is the most frequent. Periostitis, bursitis and in rare cases synovitis in the elbow joint can be complications connected with the inflammation of the tendons.

The symptoms of the disease are soreness and possible tumour localized in caput commune but no limitation of movement of the elbow joint. Generally the pains do not occur when at rest. Contraction of muscles, for instance clenching of the hand, causes distinct pain.

Epicondylitis is generally caused by excessive use of the muscles of the forearm and is frequently found in housewives. However, it can also be caused by tennis and golf, the reason for its popular names: tennis and golfer's elbow. In some cases trauma can be the etiological factor.

Epicondylitis can disappear spontaneously or it can be treated with immobilization, heat (short wave, ultrasound), massage, injections with local anaesthetics or steroids (*Wetterfors, Huth et al.*), X-ray therapy and possibly operation (*de Goes & Silva*).

Ultrasonic treatment of epicondylitis has been reported by *Aldes* (1955) who treated 36 patients. Of these 31 were cured after 6 to 10 sessions. Concomitant injections of hydrocortisol in other patients gave still better results.

The u.s. intensities which we have used are 0.8 watt/cm² and the frequency 870 kHz (Siemens Sonostat 631).

PERSONAL INVESTIGATIONS

The purpose of our investigations has been to find the effect of ultrasonic treatment of epicondylitis humeri.

TABLE 1

T ted	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
every day	10	86	9	9	1	4	5	9
every other day	6	53	9	18	1	2	3	5
	16	139			2	6	8	14

The material consisted of 16 patients with epicondylitis humeri treated at the Department of Physical Medicine and Rehabilitation Rigshospitalet Copenhagen during the last two years

The age of the patients varied from 18 to 67 years with a mean age of about 50 years There were 10 women and 6 men In 3 cases the disease was caused by trauma and in the remaining by repeated working stress

In 7 patients the symptoms were right sided in 8 patients left sided and in 1 patient both right and left sided In 8 patients the localization was lateral in 4 patients medial and in 4 patients bilateral The symptoms had been present from two weeks to two years U s treatment has been given daily and every other day

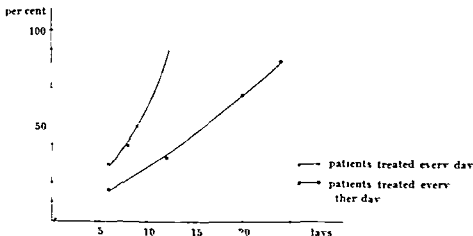


Fig 1

The patients who get u s treatment every day were recovered or cured about twice as quickly as the patient treated every other day

A total of 139 sessions was given—i e 9 sessions per patient A minimum of 3 and a maximum of 12 sessions were given

The distribution of patients treated every day and every other day is seen in Table 1

Fig 1 shows that more rapid effect improvement and recovery are obtained by daily treatment than by treatment every other day

The 2 patients whose condition is unchanged have received 8 and 12 sessions

SIDE EFFECTS

Objective damage of skin muscles tendons joints and bones was not observed in any of the patients

The patients indicated no subjective side effects of any kind

CONCLUSION

Having treated some patients daily and some every other day we think we have obtained a certain control over the effectiveness of the u.s treatment. The patients of the two groups were picked out at random

Our investigations show (Fig 1) that the patients recovered or were cured about twice as quickly by daily treatment as by treatment every other day

No other therapy was used concomitant with u s treatment

This seems to prove that u s treatment of epicondylitis is an effective and painless treatment with no side effects

SUMMARY

16 patients with epicondylitis humeri were treated with u s Of these 14 patients got better or were cured after 9 sessions on an average Patients treated daily recover nearly twice as quickly as patients treated every other day This seems to prove the effectiveness of u s treatment.

RESUME

16 malades avec epicondylite humerale ont ete traites par ultra sons L etat de 14 ces malades s est trouve ameliore ou gueri apres une moyenne de 9 seances Les malades traites chaque jour se guerissent deux fois plus rapidement que les malades traites tous les deux jours Cela semble prouver l efficacite du traitement par ultra sons

ZUSAMMENFASSUNG

16 Patienten mit Epicondylitis humeri wurden mit u s behandelt Von diesen wiesen 14 Patienten eine Besserung oder Heilung nach durchschnittlich 9 Behandlungen auf Patienten die täglich behandelt wurden waren beinahe doppelt so rasch wiederhergestellt als Patienten die nur jeden zweiten Tag behandelt wurden Dieser Umstand scheint die Wirksamkeit der u s – Behandlung zu beweisen

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A NEW DYNAMOMETER FOR MEASURING THE ISOMETRIC STRENGTH IN HUMAN FINGER FLEXORS

By

BENT LØSKOV and FLEMMING BONDI PETERSEN

Routine estimation of strength in the finger flexors is a clinical procedure the result of which is recorded according to *Seddon* (1943) in values ranging from zero (no strength) to five (Full strength). This grading, of course, is somewhat arbitrary and the reproducibility even in the hands of a well trained examiner is somewhat dubious. The shortcomings of the method are intensified if the patient is subsequently tested by different examiners.

An objective estimation of strength in the flexor digitorum sublimis and profundus muscles is useful or indispensable in a number of situations, viz. in postparalytic conditions, in training, after nerve and tendon repair, and in cases where a sublimis tendon is wanted for reactivation of thumb or finger function other than the original one.

In an attempt to obtain a more objective estimation than the above mentioned, the authors have designed a finger flexor dynamometer to be described in the following.

THE APPARATUS

The dynamometer registers the isometric muscle strength as a torque by means of strain gauges glued to a steel spring. This is the fundamental principle in various recent test methods (*Darcus* (1951), *Asmussen et al.* (1959)).

The dynamometer here described is designed for testing the strength of the proximal and distal interphalangeal (IP.) joints of the right third finger exclusively. However, it can easily be modified for testing of these joints on any finger.

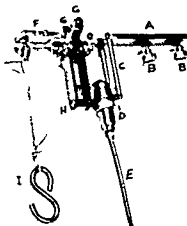


Fig 1

The Dynamometer A brass bar 150 × 25 × 5 mm F brass bar 50 × 25 × 5 mm G ball bearings connecting A with F H U shaped steel spring the left leg of which is furnished with two strain gauges one on either side B nuts for screwing the dynamometer to the plate shown in Fig 2

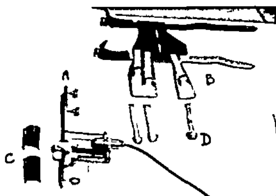


Fig 2

A the dynamometer B the handplate C the semi cylindroid splints for fixing the fingers not tested D the wedges used to obtain hyperextension in the distal phalanges

The dynamometer (Fig 1) consists of a 150 × 25 mm brass bar hinged to a 60 × 25 mm brass bar with ball bearings The axis of rotation between these bars is located 11 mm above the bar level The free rotation on the axis is prevented by a U shaped steel spring upon which the strain gauges are fastened The dynamometer is screwed on a plate

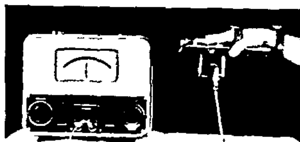


Fig 3
Hand of person to be tested mounted in the apparatus The non tested fingers can be seen hyperextended The amplifier is seen to the left



Fig 4
A closer view of the hand seen in Fig 3

to which the second fourth and fifth fingers can be immovably fixed eventually with the distal IP joints hyperextended (Fig 2) A Philips direct reading measuring bridge PR 9300 (Fig 3) was used for registering the results The calibration was carried out with known torques and registered in kg × cm Thus it was possible to record a virtually rectilinear calibration curve, which was utilized in judging the test results Maximal deflection on loading corresponded to approximately 19 kg × cm in largest amplification and in the second largest amplification to approximately 63 kg × cm The inaccuracy of the individual reading was estimated to between one and three per cent

TEST METHOD

It was our purpose to obtain an impression of the isometric strength in m flexor digitorum sublimis and profundus

Flexion of the distal IP-joint is an exclusive profundus muscle effect whereas flexion of the proximal IP joint is brought about by profundus

as well as sublimis action However it is usually possible to eliminate the profundus action on the proximal IP joint if the distal IP joints of the non tested fingers are fixed in hyperextension (*Apley* (1956)) In testing of the proximal IP joint of the third finger this phenomenon was utilized by interposing wedges under the distal phalanges of the remaining fingers These were immobilized under semi cylindroid splints (Fig 4) which could be mounted on the dynamometer During testing of the distal IP joint the proximal phalanx was immobilized in a similar manner *During the tests the third finger was strapped to the dynamometer* in a position where the axis of the latter and that of the IP joint were coincident Thus is was ensured that only the forces acting upon the joint were registered

Each person tested was urged to exert his maximal isometric strength in three consecutive periods of 2 to 4 seconds duration each

RESULTS

Five females (age 19–26) and five males (age 23–30) were tested Table 1 shows the results of the testings on the IP joints of the right third finger and the mean values of maximal in the two sexes

TABLE 1

Isometric strength is kg × cm of the right third finger during flexion of the proximal and distal IP joints The means of the maximae and their standard error are indicated for the two sexes

Subject	Age	Sex	Proximal IP joint				Distal IP joint			
			Results of 3 tests			Max	Results of 3 tests			Max
BR	19	F	18.1	18.1	16.5	18.1	5.7	6.4	5.3	6.4
HA	24	F	15.9	17.3	17.3	17.3	6.0	6.4	5.3	6.4
KI	21	F	15.4	15.1	15.6	15.8	5.4	5.0	5.4	5.4
LK	26	F	16.4	15.8	15.1	16.4	5.8	6.0	6.4	6.4
EJ	23	F	10.1	10.1	10.1	10.1	5.8	5.8	6.0	6.0
					Mean	15.5 ± 1.2			Mean	6.1 ± 0.2
FBM	27	M	31.1	29.0	29.0	31.1	9.8	10.9	11.2	11.2
KA	26	M	26.5	29.6	25.8	29.6	9.6	9.8	9.6	9.8
HN	23	M	25.6	25.6	19.3	25.6	6.9	6.9	6.6	6.9
FBP	30	M	25.5	25.0	25.8	25.8	10.9	12.7	10.8	12.7
JL	30	M	28.1	24.0	19.9	28.1	9.6	9.6	9.0	9.6
					Mean	28.0 ± 1.1			Mean	10.1 ± 1.0

DISCUSSION

As shown in table I there was only a slight variation between the individual measurings which was considered to reflect the quality of the dynamometer inasmuch as it did thus fulfil the indispensable conditions of a test method namely 1) objectivity 2) slight inaccuracies 3) reproductibility and 4) low dispersal on repeated readings.

It was not quite certain that hyperextension of the distal phalanges of the second, fourth and fifth fingers always totally eliminated the profundus action on the proximal IP joint of the third finger during the sublimis testing here. At least it was our impression that considerable individual variations did exist but no attempt was made to investigate this problem.

An interesting additional finding should be mentioned. It was found that dorsiflexion from a neutral position of the radio-carpal joint (180°) did not measurably augment the strength of the finger flexors. This was contrary to the prevalent conception that within certain limits the strength of a muscle—ceteris paribus—is augmented during stretching. On the other hand the flexor strength was decreased during volar flexion of the radio-carpal joint from the neutral position. This is in accordance with the above mentioned observations. However, this problem was not within the scope of the present work so no attempt was made to investigate it under systemically varied circumstances.

SUMMARY

A new finger flexor dynamometer is described which registers the isometric torques developed about the interphalangeal (IP) joints. The present specimen was constructed for testing of the IP joint of the third finger but the apparatus could easily be modified for testing of the second, fourth and fifth fingers. The torques were registered by means of strain gauges and a direct reading measuring bridge. The inaccuracy of the individual readings was estimated to 1–3 per cent. Five females (age 19–26) and five males (age 23–30) were tested. The isometric torque of the proximal IP joint of the third right finger was 1[illegible] ± 1.2 kg × cm and 28.0 ± 1.1 kg × cm for females and males respectively, and the corresponding values for the distal IP joint were 6.1 ± 0.2 kg × cm and 10.1 ± 1.0 kg × cm respectively.

RÉSUMÉ

Il est donné la description d'un nouveau dynamomètre de flexion des doigts qui enregistre le moment de force isométrique autour des arti

culations interphalangiennes Le present specimen a eté construit pour controler l articulation interphalangienne du majeur mais l appareil *peut facilement etre modifie pour controler* l index l annulaire ou l auriculaire Les moments de flexion sont enregistres au moyen de jauges d effort et d un pont sur lequel on peut relever directement la mesure Les erreurs individuelles de lecture sont evaluees entre 1 et 3 % Cinq femmes (agees de 19 a 26 ans) et cinq hommes (ages de 23 a 30 ans) ont subi le test Pour l articulation interphalangienne proximale du majeur droit le resultat a éte de 15 5 ± 1 2 kg × cm et de 28 0 ± 1 1 kg × cm respectivement chez les femmes et chez les hommes et les valeurs correspondantes pour l articulation interphalangienne distale furent de 6 1 ± 0 2 kg × cm et de 10 1 ± 1 0 kg × cm respectivement

ZUSAMMENFASSUNG

Ein neues Fingerbeuger Dynamometer wird beschrieben das die isometrischen Drehmomente verzeichnet die sich an den interphalangeal (IP) Gelenken entwickeln Das vorliegende Exemplar wurde konstruiert um das IP Gelenk des dritten Fingers zu prüfen aber der Apparat kann ohne weiteres zur Prüfung des zweiten vierten und fünften Fingers eingerichtet werden Die Drehmomente wurden mittels Belastungsmessungen und einer Messungsbrücke mit direkter Ablesungen registriert Die Ungenauigkeit der einzelnen Ablesungen wurde auf 1–3 % geschatzt Fünf Frauen im Alter von 19–26 Jahren und fünf Männer (23–30 alt) wurden gepruft Das isometrische Drehmoment des proximalen IP Gelenk des dritten rechten Fingers war 15 5 ± 1 2 kg × cm und 28 0 ± 1 1 kg × cm fur Frauen beziehungsweise fur Manner und die entsprechenden Werte für das distale IP Gelenk waren 6 1 ± 0 2 kg × cm und 10 1 ± 1 0 kg × cm beziehungsweise

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THE INFLUENCE OF SPINAL MOVEMENTS ON THE LUMBAR INTRADISCAL PRESSURE AND ON THE TENSILE STRESSES IN THE ANNULUS FIBROSUS

By

ALF NACHEMSON

In the late 19th century it was observed that bending movements in the lumbar spine cause a strong protrusion of the annulus fibrosus on one side combined with a contraction on the other side (*Fick* 1904). This observation has later been verified by several other authors, among them *Brown, Hansen & Yorra* (1957).

The conclusion to be drawn from this is that bending movements in the lumbar spine subject different parts of the intervertebral disc to varying mechanical stresses. No attempt has been made, however, to determine these variations.

The facets have usually been considered as important only in preventing sliding movements and rotation of the vertebrae (*Fick* 1904, *Keyes & Compere* 1932, *Hagelstam* 1949 and others). It is also known that when the arches are separated from the vertebral bodies the column of arches and facets contract while the column containing the vertebral bodies will elongate. This is said to be due to the so called "intrinsic pressure" of the nucleus pulposus (*Petter* 1933) and also to the fact that ligaments and capsules around the posterior bony elements are under some tension (*Hagelstam* 1949, *Steindler* 1955).

On vertical loading of the lumbar spine, arches and facets have been said to carry no load at all (*Fick* 1904, *Spurling* 1953), to carry around 15 % (*Nachemson* 1960) or to be "important force bearing structures" (*Kelly* 1958).

The purpose of this study has been by means of direct measurements to analyse the stresses that appear in different parts of the loaded lumbar disc tilted in various directions with and without arches, facets and ligaments.

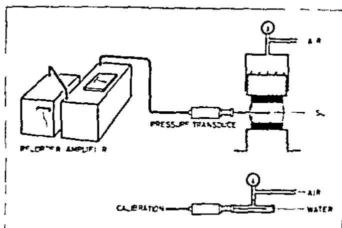


Fig 1
Schematic drawing of the apparatus in use



Fig 2
Schematic drawing of the needle and the attached plastic tubing (P E. 90) used for intradiscal pressure measurement

From a clinical point of view there are grounds for a closer study of these stresses as the symptoms of low back pain are often discussed in terms of mechanical forces on the lumbar intervertebral discs

METHODS

By inserting a soldered Luer Lok needle with a hole in the side near the tip over which an elastic polyethylene tubing is threaded into the nucleus pulposus it is possible to measure the pressure produced by loading a lumbar intervertebral disc via a superior intervertebral body in a vertical direction (*Nachemson* 1960) The procedure is based on the following principle First the pressure sensitive gauge coupled to an electromanometer is calibrated for known pressures The gauge is then inserted centrally into the disc When its position has been checked with roentgenograms in two planes the specimens are loaded vertically in a compression apparatus worked by compressed air The load is transmitted to the disc by two planoparallel plates the lower one of which is fixed while the upper plate is movable in the vertical direction

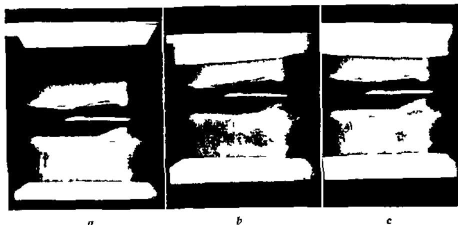


Fig 3

Roentgenographic appearance of the disc (no 4/L[illegible]) shown in Fig 5 The pictures demonstrate *a)* the position of the non tilted disc between the jaws of the compression apparatus (load is not applied) *b)* forward tilt of 5° *c)* backward tilt of 5°

(Figs 1 and 2) (For a more detailed description of the method see *Nachemson* 1960)

Readings of the intradiscal pressure were taken at loads of 40 85 130 175 and in some specimens 220 kp Following this a brass plate specially constructed with its load bearing surfaces tilted at an angle of 5° to each other was mounted onto the upper movable part of the compression apparatus On renewed loading the specimen was subjected to an assymmetrical stress In all cases the specimens have been loaded with the angle of the plate directed both forward and backward and in some instances sideward as well (Fig 3) As a check on conclusion of these tilted loading experiments the plate was removed and the discs reloaded in the vertical non tilted direction In no instance has any difference been noted in the values recorded before and after the tilted loadings The pressure was always measured with the opening of the pressure sensitive gauge pointing upwards as well as sideways

Lumbar spines taken at post mortem 12–36 hours after death have been used If the experiments were not carried out the same day the specimens were kept 1–5 days in deep-freeze (—25° C) in plastic bags It has been found that this storage has no appreciable effect on the results (*Nachemson* 1960) The departments of pathology wished to preserve the sacrum For this reason the lumbar spine was removed by sectioning through the lumbo sacral disc thus only four lumbar

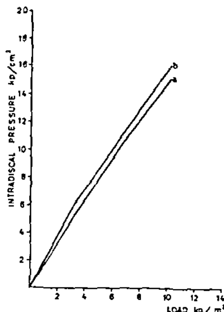


Fig 4

Intradiscal pressure in kp/cm resulting from increasing external l a l on the disc shown in Fig 5 a) non tilted b) 5 backward tilt The basic data are given in Table 3 p 190

discs were used during the experiments viz the disc just above the lumbo sacral which has been called L 4 the one above that L 3 etc In general the discs were prepared so that they were cut out with slices of adjacent vertebral bodies 1-1½ cm thick

During the experiments is was found that the values obtained from the specimens where the pedicles and joint processes were saved could not be compared to those from the experiments where they were cut off because of the difference in the direction of the applied vertical load This fact will be subject to further analysis in the discussion

In the first series (series A) the pedicles and joint processes and attached muscles were removed The cut surfaces of the vertebral bodies were made as parallel to each other as possible and also parallel to the end plates of the disc The parallelism was checked with a water level Because of technical difficulties however it was found that this parallelism not always was exact The maximum deviation from parallelism has been estimated at about 2 When not all first four lumbar discs were used in the experiments the rejected specimens had been damaged in some way This occurred most often at post mortem or when removing the lumbar vertebrae

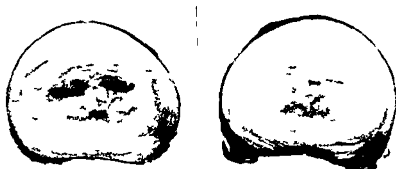


Fig 5

Macroscopic view of the disc L2 from a female age 34 The roentgenographic appearance of this disc was shown in Fig 3 the experimental results in Table 3

After the experiments the discs were cut through horizontally and their surface area was measured with a planimeter A graph was drawn for every disc with the external load in kp/cm on the abscissa and the corresponding intradiscal pressure in kp/cm on the ordinata as in Fig 4 The intradiscal pressures corresponding to external loads of 2 4 6 8 10 and in some cases 12 kp/cm were read from these curves It was seen that the intradiscal pressure was approximately proportional to and greater than the applied load per unit area This procedure makes it possible to compare results for different discs

Since the method described above is not reliable for pressure measurement inside severely degenerated discs (Nachemson 1960) this category has been excluded from the present material All the discs included here have either been normal or showed only slight macroscopic changes in the nucleus pulposus The nucleus was somewhat fibrous but could be clearly distinguished from the annulus which was intact It has earlier been proved that discs showing slight macroscopic changes such as fibrosis of the nucleus pulposus and isolated fissures in the annulus fibrosus also show hydrostatic behaviour and intradiscal pressures not differing from less degenerated discs

As mentioned earlier the discs have been loaded vertically in a compression apparatus both between two parallel plates and between two plates tilted forwards backwards and towards the left or right so as to form an angle of 5 with each other In the first instance the loading conditions were identical with those studied earlier by the author It should be pointed out that these conditions do not exactly duplicate the

stress on a disc in situ in a straight back. The procedure adopted for preparing the specimens as described above, in which the load bearing surfaces of the discs were *made parallel after removal of arches, pedicles and facets*, means that these surfaces are not parallel in situ, owing to the well known fact that the spine straightens out somewhat on removal of the posterior bony elements. This means that in a straight "unloaded" back the discs actually are under a certain amount of pressure (*Petter* 1933, *Hagelstam* 1949, *Steindler* 1955). *In the first series (A) it has* therefore been found expedient to base the experiments on the truly unloaded disc, which means that the tilt is defined in relation to the isolated specimen and not in relation to the disc in situ. The terms "forward tilt" and "backward tilt" should consequently also be interpreted *from this point of view*.

In the following series (B) the specimens were prepared so that the two vertebrae adjoining the disc and the joint processes with attached ligaments were saved. Thus a posterior connection was formed from the upper to the lower of these vertebral bodies. Also, the surfaces of the vertebrae were *levelled off by a file and the parallelism was checked* by water level. The measurements were performed as described above.

After the experiments it was also noted that when the posterior elements were removed the distance between the posterior parts of the vertebrae widened somewhat so that the earlier planoparallel loading surfaces made a forward inclination to each other at an angle of about 3°.

RESULTS

Series A

Experiments were performed on 29 discs from 10 individuals (Table 1). In no single disc has any deflection been recorded on insertion of the needle in the non tilted discs, which is entirely consistent with earlier observations. Since all specimens included in this series were practically normal or non degenerated, their hydrostatic behaviour has been taken for granted (*Nachemson* 1960). Nevertheless, as a check a calculation has been made of the difference between the vertical and the horizontal pressure. In no single measurement has the absolute deviation from the mean exceeded 7 per cent. Neither forward, backward nor sideward tilt has produced any change in the hydrostatic behaviour of the nucleus pulposus.

Twenty one discs from 6 individuals (nos. 1–6 in Table 1) have been subjected to experiments with forward and backward tilt. The pressure

TABLE 1

Specimens studied

Series A

Case no	Sex	Age (years)	Main cause of death	Discs tested
1	Female	40	Fractura cranii	L2 L3
2	Male	33	Cirrhosis hepatis	L1 L2 L3 L4
3	Male	35	Fractura cranii	L1 L2 L3
4	Female	34	Intox barbitur	L1 L2 L3 L4
5	Male	57	Cirrhosis hepatis	L1 L2 L3 L4
6	Male	33	Nephropathia c uremia	L1 L2 L3 L4
7	Female	3[illegible]	Toxic gravidarum	L1 L2 L4
8	Female	52	Haemorrhagia cerebri	L3
9	Female	[illegible]0	Tumor colli cervicalis	L1 L3
10	Male	37	Fractura cranii	L1 L3

All discs showed only very small changes in the nucleus and were classified as normal

TABLE 2

Series A

Mean values of pressure in nucleus pulposus in kp/cm² ± error of the mean in the non tilted position and vertical loading

Level		L1	L2	L3	L4
Load kp/cm²	2	3.18 ± 0.16	3.3[illegible] ± 0.35	3.47 ± 0.17	3.30 ± 0.10
	4	6.[illegible]0 ± 0.60	6.48 ± 0.54	6.47 ± 0.21	6.45 ± 0.33
	6	8.98 ± 0.79	9.40 ± 0.72	9.38 ± 0.29	9.[illegible]5 ± 0.14
	8	11.[illegible]8 ± 1.0[illegible]	12.08 ± 0.97	11.87 ± 0.5[illegible]	11.[illegible]5 ± 0.18
	10	14.[illegible]0 ± 0.8	14.70 ± 1.15	14.6[illegible] ± 0.44	14.25 ± 0.[illegible]7
		n = 5	n = 6	n = 6	n = 4

values obtained with loading in the non tilted position are set down in Table 2 together with the mean errors. These values agreed entirely with earlier observations. As in earlier studies it has been shown that each particular load test produces an identical reaction in levels L1, L2, L3 and L4.

Table 3 shows the results for one particular disc shown in Fig. 5. This table clearly demonstrates the increase in pressure effected by a tilt in different directions.

The magnitude of the increase in pressure resulting from forward and backward tilt is shown in Table 4 which includes the mean values together with the corresponding maximum and minimum values. The

TABLE 3

Series A

Prep 6/L2

Intradiscal pressures obtained from the L2 disc of a female age 34 when subjected to vertical loading in the non tilted forward and backward tilted position

Intradiscal pressure kp/cm²			
Load kp/cm²	Untilted	Tilt 5° forward	Tilt 5° backward
2	3.2	3.8	3.7
4	6.4	7.3	7.2
6	9.5	10.2	10.1
8	12.3	12.9	13.0
10	14.9	15.5	15.9

TABLE 4

Series A

Increase in intradiscal pressure resulting from 5° forward tilt

Disc	Mean value kp/cm²	Max value kp/cm²	Min value kp/cm²
L1 (n = 5)	1.04	1.41	0.62
L2 (n = 6)	0.80	1.08	0.32
L3 (n = 6)	0.63	1.32	0.06
L4 (n = 4)	0.68	1.48	0.02
Increase in intradiscal pressure resulting from 5° backward tilt			
L1 (n = 5)	0.78	1.22	0.60
L2 (n = 6)	0.68	0.82	0.54
L3 (n = 6)	0.75	1.34	0.22
L4 (n = 4)	0.40	0.68	0.22
Average Increase	0.72 kp/cm		

relatively large difference between the maximum and minimum values is probably due to the difficulty of producing entirely planoparallel surfaces in the specimens

A "sign" test has shown that a 5° forward or backward tilt results in an increase in pressure which observation is significant at the 0.1 % level The statistical analysis further shows that this increase in pressure appears to be independent of the external load A calculation of the correlation between external load and corresponding pressure variations for the different discs gives r = 0.043 (not significant) No

TABLE 5
Series A
Relative increase in intradiscal pressure brought about by 5° tilt for different outer loads

Load kp/cm²	Non-tilted intradiscal pressure mean value L1–L4 (kp/cm²)	Increase by 5° tilt
2	3.35	21.5
4	6.44	11.2
6	9.30	7.7
8	11.93	6.0
10	14.60	4.9

relationship can consequently be demonstrated between external load and variations of increase in pressure.

In addition the effect of sideward tilt has been investigated in 8 discs from 2 individuals (nos. 5 and 6 in Table 1). It was found that a significant increase in pressure resulted of the same order of magnitude as with forward and backward tilt. No difference has been noted between the effect of right and leftward tilt.

As shown in Table 4 the increase in pressure brought about by tilting 5° in the different directions is on the whole equal for the different levels L 1–L 4 and reaches a mean value of 0.72 kp/cm².

In Table 5 the relative increase in pressure resulting from 5° tilt for external loads from 2–10 kp/cm² has been calculated.

The results reported show that the non-tilted isolated disc specimen prepared as stated above shows the lowest intradiscal pressure on vertical loading when compared with corresponding values in tilted positions.

In order to examine the effect of a forward or backward tilt on a preparation loaded corresponding to its position in situ, experiments have been carried out on 7 discs from 4 individuals (cases nos. 7–10). In these tests the load bearing surfaces of the cut vertebral bodies formed a forward angle of approximately 3° with each other following removal of the posterior elements.

The results are set down in Table 6 which shows that the mean increase in pressure, still regardless of the external load per unit area, is nil for forward tilt while the corresponding value for backward tilt is 1.5 kp/cm². The backward tilt will in these discs be 8° according to the above mentioned inclination of the load bearing surfaces.

TABLE 6
Series A
Increase or decrease in intradiscal pressure by 5° forward and backward tilt in specimens with non parallel loading surfaces (c a 3° forward angle)

Case no Disc	Forward tilt							Backward tilt						
	9 L1	10 L1	7 L2	8 L3	9 L3	10 L3	7 L4	9 L1	10 L1	7 L2	8 L3	10 L3	7 L4	9 L3
Load kp cm	Change in intradiscal pressure kp cm²													
2	+0 1	+0 3	+0 4	—0 1	—0 2	+0 3	+0 1	+0 7	+0 9	+0 7	+1 0	+1 1	+0 9	+1 5
4	—0 1	+0 5	+0 3	—0 2	—0 3	+0 1	—0 1	+1 0	+1 6	+1 0	+1 4	+1 6	+0 9	+2 7
6	±0	+0 6	+0 4	—0 4	—0 2	—0 2	—0 3	+1 3	+1 9	+1 3	+1 6	+1 6	+0 9	+3 6
8	+0 1	+0 5	+0 2	—0 8	—0 4	—0 1	—0 6	+1 4	+2 0	+1 2	+1 6	+1 6	+1 0	+3 5
10	+0 4	+0 6	+0 1	—1 0	—0 4	—0 1	—0 7	+1 6	+2 1	+1 1	+1 7	+1 6	+1 3	+3 0
	Mean change —0 034 kp/cm Differs not significantly from 0							Mean change +1 53 kp/cm This increase differs significantly at the 0 1 % level from the increase shown in table 4						

TABLE 7
Specimens studied
Series B

Case no	Sex	Age years	Main cause of death	Discs tested
11	Male	54	*Tumor cerebri*	L2 L4
12	Male	53	Asthma bronchiale	L1 L3
13	Female	30	Embolia pulm	L2 L4
14	Female	20	Tumor med spinalis	L1 L3
15	Female	56	Aneurysma cerebri	L3
16	Male	34	Fractura cranii	L1 L3

All discs showed only very small changes in the nucleus and were classified as normal

Series B

Eleven lumbar disc specimens from 6 individuals were studied (Table 7)

When inserting the pressure sensitive gauge in the unloaded disc specimen with arches and facets still attached intradiscal pressures between 0.5–1 kp/cm^2 were recorded (mean value 0.7 kp/cm^2) As earlier shown in series A the intradiscal pressure in the unloaded isolated disc specimen is zero Thus this pressure must depend on the tension in the ligaments and capsule surrounding the posterior bony elements After reading the pressure of the unloaded disc the amplifier was put in zero position and measurements were made to record the intradiscal pressures for the increasing loads as said above The increase in intradiscal pressure was linear to the outer applied load and no deviation from the hydrostatic behaviour was noted First the specimens were loaded without tilt then with a 5 forward backward and sideward tilt Between the series unloading was performed Finally the intradiscal pressure was measured for increasing vertical loads without tilt In no single case did the result from the last series of vertical load deviate from the first one The experiments in the tilted position had thus not changed the experimental conditions as was noted already in series A

In Table 8 the results from the different discs are presented A statistical analysis of the results in this table shows that there is a significant difference between the increase in intradiscal pressure caused by a 5 forward tilt on the one hand and a 5 backward tilt on the other (t test of the difference gives t = +8.412)

TABLE 8

Series B

Increase in intradiscal pressure resulting from 5° tilt in different directions in specimens with attached laminae and facets

Case No	Disc	Load kp		5° forwards kp cm	5° rightwards kp cm	5° backwards kp cm	5° leftwards kp cm
		40		0.0	+0.6	+0.9	+0.2
11	L2	85		−0.1	+0.6	+0.7	+0.1
		130		−0.2	+0.5	+0.5	+0.2
		175		−0.3	+0.7	+0.7	0.0
			$\bar{m}$	−0.15	+0.6	+0.7	+0.125
		40		0.0	+0.4	+0.4	+0.2
	L4	85		−0.1	+0.6	+0.4	+0.2
		130		−0.3	+0.8	+0.6	−0.3
		175		0.0	+0.6	+0.4	−0.2
			$\bar{m}$	−0.1	+0.6	+0.45	−0.025
		40		0.0	+0.8	+0.6	+0.4
12	L1	85		0.0	+1.0	+0.5	+0.6
		130		0.0	+1.4	+0.9	+0.7
		175		0.0	+1.3	+1.3	+0.6
			$\bar{m}$	0.0	+1.125	+0.825	+0.575
		40		0.0	+0.2	+0.2	+0.2
	L3	85		0.0	+0.2	+0.3	+0.2
		130		−0.2	0.0	+0.2	+0.2
		175		0.0	0.0	+0.2	+0.6
			$\bar{m}$	−0.05	+0.1	+0.225	+0.3
		40		0.0	+0.1	+1.0	+0.2
13	L2	85		0.0	+0.2	+1.2	+0.1
		130		0.0	+0.2	+0.9	0.0
		175		−0.1	0.0	+1.3	0.1
			$\bar{m}$	−0.025	+0.125	+1.1	+0.05
		40		+0.1	+0.2	+0.3	+0.3
	L4	85		−0.1	+0.4	+0.2	+0.1
		130		−0.2	+0.3	0.0	0.0
		175		−0.3	+0.2	−0.1	0.1
			$\bar{m}$	−0.125	+0.275	+0.1	+0.075

TABLE 8 (cont.)

Case No	D	Load kp		S forwards kp m	S rightwards kp m	backwards kp m	S leftwards kp m
		40		0.0	+0.3	+0.9	+0.9
14	L1						
		130		−0.3	+0.2	+0.8	+0.8
		175		−0.9	0.0	+0.8	+0.6
			$\bar{m}$	0.375	+0.15	+0.825	+0.725
		40		0.0	+0.6	+1.2	+0.1
	L3	85		+0.2	+0.5	+1.6	+0.3
		130		−0.1	+0.3	+1.1	−0.1
		175		+0.1	+0.1	+1.0	−0.2
			$\bar{m}$	+0.05	+0.375	+1.22	+0.025
		40		+0.1	+0.3	+0.5	+0.3
15	L3	85		−0.1	+0.3	+0.5	−0.1
		130		0.0	+0.1	+0.3	0.0
		175		+0.1	+0.1	+0.4	−0.1
			$\bar{m}$	+0.025	+0.2	+0.425	+0.025
		40		−0.3	0.0	+1.0	+0.6
16	L1	85		−0.4	+0.4	+1.3	+0.9
		130		−0.8	+0.6	+1.1	+0.6
		175		0.0	+1.0	+1.7	+0.5
			$\bar{m}$	−0.375	+0.50	+1.275	+0.65
		40		+0.5	+0.6	+1.1	+0.6
	L3	85		+0.3	+0.7	+1.7	+0.6
		130		+0.5	+1.0	+1.0	+0.8
		17		+0.5	+1.0	+1.0	+0.9
			$\bar{m}$	+0.45	+0.825	+1.2	+0.725
Mean values whole material				−0.06	+0.45	+0.76	+0.30

TABLE 9
Series B
Increase in intradiscal pressure resulting from 5° sideward tilt and increasing vertical load in specimens with and without attached arches and facets
(After the removal of the posterior bony elements the earlier planoparallel surfaces of the cut vertebrae have not been made parallel again)
Average increase (kp/cm^2)

Case no	Disc	5° rightw. tilt with arches and facets	5° rightw. tilt without arches and facets	5° leftw. tilt with arches and facets	5° leftw. tilt without arches and facets
14	L1	+0.2	+0.7	+0.7	+0.6
	L3	+0.4	+0.8	0.0	+1.1
15	L3	+0.2	+0.5	0.0	+0.[illegible]
16	L1	+0.5	+1.1	+0.7	+1.6
	L3	+0.8	+1.5	+0.7	+0.5
Mean values of all observations (n)		+0.4 (20)	+0.9 (25)	+0.4 (20)	+0.8 (25)

The difference between 5° sideward tilt to the left and to the right is not significant ($t = +1.212$). A forward tilt of 5° on disc preparations with intact arches and facets gives no rise in intradiscal pressure compared with the same vertical load in the untilted position. A backward tilt of 5° gives compared to the untilted case an increase of 0.76 kp/cm^2.

In Table 9 the differences of pressures in kp/cm^2 are shown which were observed on increasing vertical loads in the untilted position and on 5° sideward tilt both in the intact preparations and in the same preparations after resection of the posterior elements. In the last mentioned series, however, the load bearing surfaces were not made planoparallel. Such experiments were performed on 5 discs from 3 individuals according to Table 9.

DISCUSSION

The results in series A show that the intradiscal pressure in a lumbar intervertebral disc at a tilt forwards, backwards or sidewards at vertical loads of 2–10 kp/cm^2 is higher than the intradiscal pressure at the same vertical load in a non tilted disc. The explanation of this phenomenon is probably connected with the fact that the lateral expansion of the annulus varies nonlinearly with a decrease in distance between the vertebral bodies, so that the greater the decrease in distance the less the increase of the lateral expansion per unit of compression (Fig.

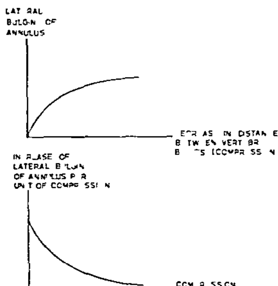


Fig 6

The compression of a disc gives a lateral bulging of the annulus This bulging however varies nonlinearly with the compression When compression increases the increase in lateral bulging decreases

b) The same property also applies to the changes of areas inside the lateral bulge on a vertical section of the disc as shown in Fig 7

On comparison of a non tilted with a tilted disc loaded with the same total force approximately half of the circumference of the annulus will in the latter be more and the other half less compressed than in the non tilted disc

Due to the earlier mentioned nonlinearity there will in the tilted case be a tendency to somewhat less space left to the nucleus Since the nucleus has a very low compressibility (*Fick* 1904 *Joplin* 1935 *Happey et al* 1953) the pressure inside the nucleus will consequently be higher The fact that this tendency expressed as a percentage is most pronounced with lower external loads (Table 5) is immediately explained by the circumstance that the nonlinearity is most marked for slight compressions so that the variation in the lateral bulging per unit of compression is greatest for these lower loads

It has been mentioned before that the procedure adopted for preparing the specimens involves that the discs in series A when loaded "vertically" have been subjected to a somewhat asymmetrical stress in the vertical plane in relation to their position in situ However the re

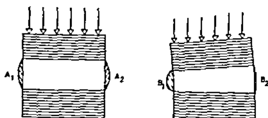


Fig 7

A tilt of 5° in a vertically loaded isolated disc specimen will result in a tendency to **lessening of the space occupied by the nucleus pulposus and thus to an increase of the intradiscal pressure**

Technical comment

In the Fig 7 the area B_1 is 10 % larger than the area A_1 whereas the area B_2 is 30 % smaller than the area A_2. These percentages are somewhat arbitrarily chosen but the trend can be estimated by the following calculation. An area such as A_1, A_2, B_1 and B_2 is called A (see Fig 8), the corresponding distance between the vertebral bodies is called l and the length of the arc (annulus fibrosus) is called l_0.

One finds

$$A \approx \frac{l_0}{\sqrt{6}} \sqrt{1 - \frac{l}{l_0}}$$



Fig 8

Thus for instance for a disc with $l_0 = 12$ mm, if $A_{1,2}$ corresponds to $l = 11$ mm, B_1 to $l = 10.5$ mm and B_2 to $l = 11.5$ mm, then B_1 will be about 20 % larger than *A_1 whereas B_2 will be about 30 % smaller than A_2*

sults also show that non-tilted discs, as defined in series A, assume as it were a position of repose, as the intradiscal pressures in this position in practically all experiments fall below those obtained at a tilt, whether forwards, backwards or sidewards.

The fact that the non-tilted disc as defined above represents a *minimum of the intradiscal pressure* leads to an estimation of the relation between tilt and increase of intradiscal pressure as shown in Fig 9.

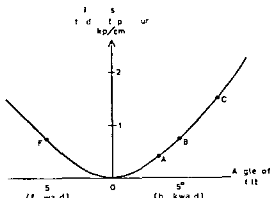


Fig 9

Relation between tilt and increase in intradiscal pressure O — non tilted isolated disc specimen A — zero position in situ B and F — increase noted by 5° backward and forward tilt C — increase noted by about 8° backward tilt

Thus it can be expected that a tilt of more than 5° may lead to an appreciably larger increase in intradiscal pressure a fact which is also supported by results obtained with the specimens shown in Table 6 where there has been a backward tilt of about 8° The surfaces of the cut vertebrae in these specimens were already in the unloaded position at a 3° forward angle to each other With the brass plate in the 5° backward tilt position this means a backward tilt of about 8° in these cases

According to these results the increase following from 8° backward tilt will be 1.5 kp/cm² The increase from 5° to 8° of backward tilting will thus raise the change in intradiscal pressure more than 100%

When tilting 5° forward from the in situ position (Table 6 Forward tilt) no change in intradiscal pressure was seen The explanation for this follows immediately when looking at Fig 9 In this case the movement starts at the point A and stops in the middle between O and F

It has earlier been shown that the vertical stress in the annulus is comparatively small on vertical loading owing to the relatively high pressure in the nucleus pulposus The tangential stress however is rather high and it has been calculated to exceed the total load per unit of area 3–5 times at least in the dorsal part of the annulus (*Nachemson* 1960)

The increase in intradiscal pressure resulting from tilt will thus increase this tangential stress even more The relationship between the

tangential stress in the dorsal part of the annulus and the intradiscal pressure is given in the following formula

$$\sigma_{tt} = \frac{2b\,(2b + a_t)}{a_t\,(4b + a_d + a_t)}\, p_n$$

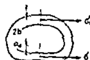


Fig 10

where p_n means the measured intradiscal pressure and the other symbols are explained by Fig 10

Now for the disc shown in Figs 4 and 5 the following values were found (Table 3)

a_v = 7 mm 2b = 25 mm a_t = 4 mm p_n = 6.4 kp/cm² non tilted resp 7.2 kp/cm² at backward tilt for the external load of 4 kp/cm² while for the external load of 10 kp/cm² p_n = 14.9 resp 15.9

With a load of 4 kp/cm² backward tilt will produce an increase of σ_{tt} from 20.6 to 23.2 kp/cm² whereas the corresponding increase for a load of 10 kp/cm² will be from 48.1 to 51.3 kp/cm². If the backward tilt had been increased to about 8° there would according to the results shown in Table 6 have been corresponding increases of σ_{tt} to 25.9 kp/cm² and 54.1 kp/cm² respectively

Tilting will consequently not only appreciably increase the vertical stress in the annulus on the side which is most compressed but also *increase the tangential stress in the entire annulus which in the narrower dorsal part in some cases may cause a stress which is up to 25 per cent higher than that produced by vertical loading* With a backward bending movement the annulus will here simultaneously be subjected to a very heavy stress both in the vertical and horizontal directions It can probably be said that this may form the mechanical background for ruptures of the annulus in the lumbar intervertebral disc

When discussing the results obtained in series B it must be clear that it is not possible directly to compare the two series as the direction of the applied load varies between them In series B the specimens when subjected to untilted loading have the same or nearly the same position as when in situ in the vertebral column Even unloaded the intradiscal pressure in such specimens is between 0.5 and 1.0 kp/cm² When the posterior elements are cut off the earlier planoparallel weight bearing surfaces form a forward angle of about 3° with each other Thus the

"in situ" position in itself means backward tilt of the disc of about 3° compared to the so-called resting or zero position of the disc.

In the isolated specimens of series A it was shown that an increase from 5° to 8° backward tilt will raise the change in intradiscal pressure more than 100 % from 0.7 to 1.5 kp/cm².

When a specimen with arches and facets still attached is loaded vertically at a tilt of 5° forwards no significant rise of intradiscal pressure was noted compared to the rise in intradiscal pressure in the untilted and vertically loaded specimen. On loading at a 5° backward tilt the increase in intradiscal pressure that occurs is independent of the outer applied load and reaches about 0.8 kp/cm². If the pressure of about 0.7 kp/cm² observed from the start in these preparations already when unloaded is added there will subsequently be an increase of intradiscal pressure of about 1.5 kp/cm².” From Fig. 9 is seen that a backward tilt of 8° in the isolated disc specimen gives an increase in the intradiscal pressure of about 1.5 kp/cm². In these cases there was no pressure when the needle was inserted in the unloaded specimens.

If those pressures that were noted when inserting the needle in the unloaded specimens with arches and facets still attached are taken into consideration the increase of intradiscal pressure brough about by a 5° backward tilt will also be 1.5 kp/cm². Thus the posterior elements in the intact specimen which is tilted 5° backward and at the same time loaded vertically do not have any certain unloading function on the disc. Nor have the posterior elements any significant effect on the rise in intradiscal pressure at a forward tilt of 5°. When the disc is loaded vertically resp. at a tilt of 5° forwards as defined in these cases there will be a symmetrical shift around the so called zero-position of the disc (O in Fig. 9).

An analysis of the effect of 5° sideward tilt in the intact specimen shows that the posterior elements do not have any significant effect on the intradiscal pressure (Table 9). If it is taken into consideration that there exists a difference in pressure of about 0.7 kp/cm² between the unloaded intact specimens on the one hand and the isolated discs on the other hand and that this difference is due to a 3° backward tilt one finds that the absolute pressure at the sideward tilt does not significantly differ in the two separate loading conditions. If at the external vertical load P the resultant intradiscal pressure is P_1 resp. P_2 then in the discs without arches the "total" intradiscal pressure = P_1 + the effect of sideward tilt. With arches and facets the pressure will be = P_2 + 0.7 kp/cm² + the effect of sideward tilt.

Thus it looks as if the facets and surrounding ligamentous structures do not have any significant effect on the pressure in the nucleus pulposus when the specimen is vertically loaded and at the same time tilted 5° forward, backwards and sidewards. It has earlier been stated (*Nachemson* 1960) that the weight bearing capacity of the posterior bony elements was about 15 % at loads in the vertical direction. This observation, however, was based on comparison between two series which can not be directly compared. It is now clear that when arches and facets are removed and the weight bearing surfaces made plano-parallel to each other, there is not the same loading condition as in the intact specimen. The "intrinsic" pressure of 0.7 kp/cm² in the intact specimen which is exerted by the ligaments and capsules around the posterior bony elements was not taken into account. If the posterior bony element have any weight bearing capacity at loads in the vertical direction it must certainly be very small, at least for loads up till 220 kp.

The human spine is subjected to relatively high loads in the vertical direction and yet it must have good bending properties. The investigations have shown that the vertically applied load to a relatively high extent is taken up by the nucleus pulposus, thus releasing the vertical stress on the annulus fibrosus. When the disc is tilted the intradiscal pressure increases, thus relatively releasing the annulus fibrosus from higher vertical stress. In that way tilting movements are made easier. If the annulus had to carry most of the total vertical load it would be rather much compressed and tilting would have been made more difficult due to the fact that further compression on the tilted side of the already compressed annulus would be almost impossible.

SUMMARY

Normal and slightly degenerated lumbar intervertebral disc specimens (L 1–L 4) taken at autopsy from 16 individuals between 20 and 57 years of age have been studied to evaluate the effect of forward, backward and sideward tilt on the intradiscal pressure.

In a vertically loaded and tilted disc the hydrostatic properties of the nucleus pulposus are not affected.

In disc preparations containing one disc and parts of adjoining vertebral bodies it has been found that compared to the intradiscal pressure in the non tilted case, the pressure in healthy or slightly degenerated specimens shows an increase on tilted loading. No difference was ob

served between L1 L2 L3 and L4 in this respect The recorded increase in pressure in absolute measure at a tilt of 5° is about 0 7 kp/cm² independently of the applied load in the interval 2–10 kp/cm²

The percentage increase produced by a tilt of 5° will be for an external load of 2 kp/cm² 22 % for 10 kp/cm² 5 % The increase in pressure and the relative diminution of this increase with higher loads is explained by the fact that the lateral bulging of the annulus fibrosus on tilted loading follows a nonlinear pattern so that the nucleus pulposus has relatively less volume at its disposal with vertical loading on a tilted than on a non tilted disc With increasing loads this effect will expressed as a percentage become less and less pronounced

The relation between tilt and increase in intradiscal pressure has been estimated and it can on the basis of the experimental findings of this examination be expected that a tilt of more than 5° may lead to an appreciably larger increase in intradiscal pressure The increase of backward tilt for example from 5° to 8° resulted in a more than double increase of pressure from 0 7 kp/cm² to 1 5 kp/cm² compared with the pressure in the non tilted disc

It can thus be demonstrated that a backward tilt not only will subject the dorsal part of the annulus fibrosus in a normal lumbar disc to an increased vertical stress but also to a tangential stress which per unit of area may be 6 or 7 times the external load This fact may form the mechanical background to the production of dorsal annulus ruptures in the lumbar intervertebral discs

In lumbar disc specimens with arches and facets still attached there exist a small "intrinsic" pressure of 0 7 kp/cm² probably exerted by the capsules and ligaments surrounding the posterior bony elements When these elements are removed no intradiscal pressure can be recorded in the unloaded discs

The changes in intradiscal pressure caused by 5° forward backward or sideward tilt in these specimens when subjected to vertical loading up till 220 kp are not influenced by the posterior bony or ligamentous elements Thus arches and facets do not have any significant effect on the tensile strains in the annulus fibrosus resulting from a forward backward or sideward tilt of 5°

The results that are presented clearly demonstrate the mechanism by which the lumbar discs manage to combine their function of withstanding a heavy vertical stress with the ability to tilt in various directions

RÉSUMÉ

Des spécimens de disques intervertébraux lombaires normaux ou légèrement dégénérés (L 1–L 4) prélevés à l'autopsie chez 16 individus âgés de 20 à 57 ans ont été étudiés afin d'évaluer l'effet de l'inclinaison antérieure postérieure et latérale sur la pression intradiscale

Dans un disque chargé verticalement et incliné les propriétés hydrostatiques du noyau pulpeux ne sont pas affectées

Dans les préparations discales contenant un disque et des parties des *corps vertébraux adjacents on a constaté que comparée à la pression* intradiscale dans les cas non inclinés la pression a tendance à accroître chez les spécimens normaux ou légèrement dégénérés qui subissent une charge en position inclinée Aucune différence n'a été observée à cet égard entre L 1, L 2 L 3 and L 4 L'augmentation maximum de la pression en chiffre absolu à une inclinaison de 5° est d'environ 0 7 kg/cm indépendamment de la charge appliquée dans l'intervalle entre 2 et 10 kg/cm

L'augmentation proportionnelle à une inclinaison de 5 est pour une charge externe de 2 kg/cm 22 % pour 10 kg/cm 5 % L'augmentation de la pression et la diminution relative de cette augmentation à des charges plus élevées s'explique par le fait que le gonflement latéral de l'anneau fibreux sous charge inclinée ne suit pas une formule linéaire Le volume du noyau pulpeux est relativement moindre lorsqu'il est posé avec une charge verticale sur un disque incliné que sur un disque non incliné Avec des charges accrues l'effet proportionnel sera de moins en moins prononcé

Le rapport entre l'inclinaison et l'augmentation a été évaluée et sur la base des trouvailles expérimentales résultant de ces études on peut considérer qu'une inclinaison de plus de 5 signifie une augmentation beaucoup plus forte de la pression intradiscale C'est ainsi que l'augmentation de 5 à 8 de l'inclinaison *postérieure* provoque une augmentation de pression de plus du double soit de 0 7 kg/cm à 1 5 kg/cm comparée avec la pression sur un disque non incliné

Il peut donc être démontré qu'une inclinaison postérieure non seulement fait subir à la partie dorsale de l'anneau fibreux d'un disque lombaire normal une tension verticale accrue mais aussi une tension tangentielle qui peut atteindre par unité de surface 6 ou 7 fois la charge externe Ce fait peut former l'arrière plan mécanique des ruptures dorsales de l'anneau dans les disques intervertébraux lombaires

Dans les spécimens de disque lombaire avec arcs et facettes encore

attaches il existe une petite pression intrinseque de 0 7 kg cm probablement exercee par les capsules et les ligaments entourant les elements osseux posterieurs Lorsque ces elements sont retires aucune pression intradiscale ne peut etre enregistree sur ces disques non charges

Les changements de pression intradiscale causes par une inclinaison anterieure posterieure et latérale de 5 chez ces specimens soumis a une charge verticale allant jusqu a 220 kg ne sont pas influences par les eléments osseux ou ligamenteux posterieurs Les arcs et les facettes n ont aucun effet important sur la sensibilite de l anneau fibreux a la tension resultant d une inclinaison anterieure posterieure ou laterale de 5

Les resultats qui sont presentés demontrent clairement le mecanisme par lesquel les disques lombaires combinent leur fonction de resistance a un lourd effort vertical avec la possibilite d une inclinaison dans des directions variees

ZUSAMMENFASSUNG

Normale und leicht degenerierte lumbale disci intervertebrales (L 1–L 4) die anlasslich der Autopsie von 16 Personen im Alter von 20–57 Jahren erhalten worden waren wurden untersucht um die Wirkung der vorwarts ruckwarts und seitwärts Beugung auf den intradiskalen Druck zu bestimmen

Bei einem vertikal belasteten und geneigten Discus werden die hydrostatischen Eigenschaften des Nucleus pulposus nicht angegriffen

An Diskuspraparaten die einen Diskus und Teile der anliegenden Wirbelkorper enthielten wurde gefunden dass im Vergleich mit dem intradiskalen Druck bei dem nicht geneigten Falle der Druck in gesunden oder leicht degenerierten Exemplaren eine Zunahme bei schräger Belastung aufweist Keine Verschiedenheit wurde in dieser Hinsicht zwischen L 1 L 2 L 3 und L 4 bemerkt Die aufgezeichnete Druckzunahme in absoluter Messung bei einer Neigung von 5 ist ungefahr 0 7 kp cm unabhängig von der angewandten Belastung im Zwischenraum 2 10 kp cm

Die percentuelle Zunahme welche bei einer Neigung von 5 erzeugt wird wird für eine äussere Belastung von 2 kp cm 22 % fur 10 kp cm 5 % sein Die Druckzunahme und die verhaltnismassige Abnahme dieser Zunahme bei grösserer Belastung kann durch die Tatsache erklart werden dass die laterale Herausschwellung des annulus

fibrosus bei schräger Belastung einem nichtlinearen Muster folgt so dass der nucleus pulposus verhältnismässig weniger Volumen bei vertikaler Belastung auf einen geneigten als auf einen nicht geneigten Diskus zur Verfügung hat Mit zunehmender Belastung wird dieser Effekt ausgedruckt in Percenten immer weniger ausgesprochen werden

Die Beziehung zwischen Neigung und Zunahme an intradiskalem Druck ist geschätzt worden und es ist auf Grundlage der experimentellen Befunde dieser Untersuchung zu erwarten dass eine Neigung von mehr als 5 zu einer bedeutend grosseren Zunahme des intradiskalen Druckes führen kann Die Zunahme der Ruckwartsneigung von 5 bis zu 8° ergab zum Beispiel eine mehr als doppelte Druckzunahme von *0 7 kp/cm bis zu 1 5 kp/cm²* verglichen mit dem Druck in dem nicht geneigten Diskus

Es kann daher gezeigt werden dass eine Ruckwärtsneigung den dorsalen Teil des annulus fibrosus in einem normalen lumbalen Diskus nicht nur einer zunehmenden vertikalen Beanspruchung unterwerfen wird sondern auch einer tangentialen die per Flächeneinheit 6–7 malgrosser sein kann als die äussere Belastung Diese Tatsache bildet moglicherweise den mechanischen Hintergrund fur die Entstehung vor dorsalen Annulusberstungen der Lendenzwischenwirbelscheiben

In lumbalen Diskuspraparaten an denen Bogen und Fazetten noch vorhanden sind besteht ein kleiner innerer Druck von 0 7 kp/cm der wahrscheinlich von den Kapseln und Bändern die die ruckwärtigen Knochenelemente umgeben ausgeubt wird Wenn diese *Elemente entfernt* werden kann man keinen intradiskalen Druck am unbelasteten Diskus verzeichnen

Die Veranderungen im intradiskalen Druck welche durch 5 Vorwärts Ruckwarts oder Seitwartsneigung in diesen Praparaten hervorgerufen werden wenn sie einer vertikalen Belastung bis zu 220 kp unterworfen werden werden nicht von den ruckwärtigen knochernen oder Bandelementen beeinflusst Es haben daher Bogen und Fazetten keinen bedeutsamen Effekt auf die Dehnungsbeanspruchungen des Annulus fibrosus die sich aus einer Vorwarts Ruckwarts oder Seitwartsneigung von 5 ergeben

Die hier vorlegten Ergebnisse zeigen in klarer Weise den Mechanismus durch den die lumbalen Zwischenwirbelscheiben es vermogen ihre Funktion des Widerstandes gegen schwere vertikale *Beanspruchung* mit der Fähigkeit sich in verschiedenen Richtungen zu neigen zu

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fibrosus bei schräger Belastung einem nichtlinearen Muster folgt, so dass der nucleus pulposus verhältnismässig weniger Volumen bei vertikaler Belastung auf einen geneigten als auf einen nicht geneigten Diskus zur Verfügung hat. Mit zunehmender Belastung wird dieser Effekt — ausgedrückt in Percenten — immer weniger ausgesprochen werden.

Die Beziehung zwischen Neigung und Zunahme an intradiskalem Druck ist geschätzt worden und es ist auf Grundlage der experimentellen Befunde dieser Untersuchung zu erwarten, dass eine Neigung von mehr als 5° zu einer bedeutend grösseren Zunahme des intradiskalen Druckes führen kann. Die Zunahme der Rückwärtsneigung von 5° bis zu 8° ergab zum Beispiel eine mehr als doppelte Druckzunahme von 0.7 kp/cm² bis zu 1.5 kp/cm², verglichen mit dem Druck in dem nicht geneigten Diskus.

Es kann daher gezeigt werden, dass eine Rückwärtsneigung den dorsalen Teil des annulus fibrosus in einem normalen lumbalen Diskus nicht nur einer zunehmenden vertikalen Beanspruchung unterwerfen wird, sondern auch einer tangentialen, die per Flächeneinheit 6–7 malgrosser sein kann als die äussere Belastung. Diese Tatsache bildet möglicherweise den mechanischen Hintergrund für die Entstehung von dorsalen Annulusberstungen der Lendenzwischenwirbelscheiben.

In lumbalen Diskuspräparaten, an denen Bögen und Fazetten noch vorhanden sind, besteht ein kleiner „innerer" Druck von 0.7 kp/cm², der wahrscheinlich von den Kapseln und Bändern, die die rückwärtigen Knochenelemente umgeben, ausgeübt wird. Wenn diese Elemente entfernt werden, kann man keinen intradiskalen Druck am unbelasteten Diskus verzeichnen.

Die Veränderungen im intradiskalen Druck, welche durch 5° Vorwärts-, Rückwärts- oder Seitwärtsneigung in diesen Präparaten hervorgerufen werden, wenn sie einer vertikalen Belastung bis zu 220 kp unterworfen werden, werden nicht von den rückwärtigen knöchernen oder Bandelementen beeinflusst. Es haben daher Bögen und Fazetten keinen bedeutsamen Effekt auf die Dehnungsbeanspruchungen des Annulus fibrosus, die sich aus einer Vorwärts-, Rückwärts- oder Seitwärtsneigung von 5° ergeben.

Die hier vorlegten Ergebnisse zeigen in klarer Weise den Mechanismus, durch den die lumbalen Zwischenwirbelscheiben es vermögen, ihre Funktion des Widerstandes gegen schwere vertikale Beanspruchung mit der Fähigkeit, sich in verschiedenen Richtungen zu neigen, zu vereinen.

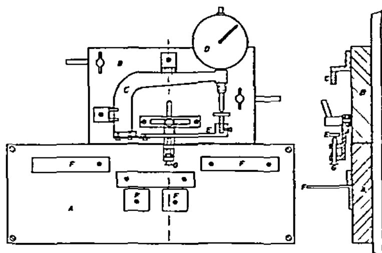


Fig 1

Apparatus for isometric mea urement of the strength of M abductor dig V A metal arm C is fixed to a plate B adjustably amounted on plate A At the end of C is a dial D To the other end of C is fastened a spring integrally connected with a lever E. The forearm of the sul ject rests on the support A the hand to be tested is placed against the support F and the key G is a ljusted to abut upon the ulnar ed e of the distal interphalangeal joint of the small finger Movements of the key G are trans mitted via the lever E to the dial D

concentric exercises were superior to the isometric under experimental conditions simulating those under which such exercises must as a rule be performed by patients

MATERIAL

M abductor digiti V of the right hand (left hand if left handed) was selected for the trial This muscle is a mover and used rather little in daily life Its strength is usually small but can be increased considerably by both static and isotonic concentric exercise (*Iiberson et al* 1958)

Female physical therapy students aged 18-28 (average 21-22) were selected for the trial

The group used for evaluation of *isometric* training consisted of 41 students and a control group of 41 other students The design and use of the apparatus employed for testing strength is given in Figs 1 and 2

The series used for evaluation of *isotonic concentric* training consisted of 44 students and 41 other students as controls The apparatus used for training and measurement of the strength is described in Figs 3 and 4

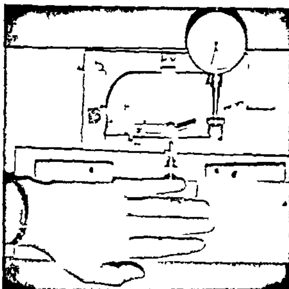


Fig 2
Subject with hand in apparatus illustrated in Fig 1

METHOD

Gallagher et al (1949) found it necessary for the subjects to get accustomed to the apparatus for measurement of strength before the recordings became reliable All the persons taking part in the present investigation were therefore given about a week to use the apparatus before the investigation proper was started

During this time the method was explained to the participants who were also given instructions individually They were informed that the purpose of the trial was to study the efficacy of the method Since *Wright* (1959) observed considerable variations in grip strength at different times of the day all exercise (and measurement) was done at the same hour of the day The subjects trained 5 days a week for 8 weeks

One group trained during the 1959-1960 term the other during 1960 1961 All the director of the trial did was to arrange for the students to have time for the trial at a given time every day

This was the only reminder they were given of the trial During measurement of the muscle strength however both the experimental group and the control group were stimulated to exert their utmost

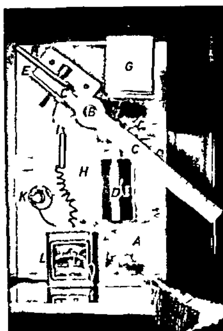


Fig 3

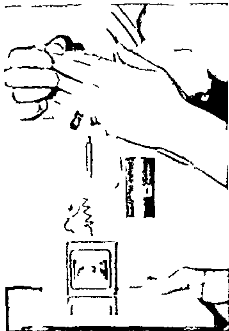


Fig 4

Fig 3 Apparatus for isotonic measurement of strength of M abductor dig V man On a frame A is mounted a horizontal pivot B carrying a balanced lever C A weight D of 750 g is suspended from one of the deep indentations in one arm of the lever The indentations are 0 25 cm apart Along the other arm of the lever is a plate E against which the small finger is pressed The hand is supported by an adjustable plate F and a support C Under the elbow is placed a support of such a height that the forearm hand and fingers are in a straight line See Fig 4 The dorso-volar axis of the metacarpo phalangeal joint of the small finger can be fairly accurately determined by palpation Judging from roentgenographs of the joint in different degrees of abduction the axis is stationary during the movement of abduction The axis of the joint is placed over the pivot B of the lever with the aid of the plumb line through B (the weighted thread H) —The small finger is placed against and parallel to the lever When the lever is pressed horizontal it closes the circuit at I and lights the lamp K The source of energy is the battery L— The distance from the pivot B to the point of suspension of the weight D is proportional to the force that must be applied to the plate F to maintain the lever horizontal One centimetre of this distance is called a unit of strength

Fig 4 Position of hand in apparatus shown in Fig 3 A mark on the back of the hand indicates the dorso volar axis of the small finger

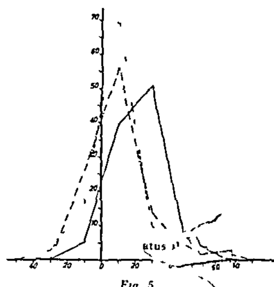


Fig 5

Result of isometric training Absci sa Percentual increase in strength during perio l of exercise Ordinate Percentual distribution of material

A *Isometric training*

The apparatus (Figs 1 and 2) for measurement of strength was cali brated both immediately before the first and immediately before the last measurements

During exercise the students worked in pairs One fixed the other s right (or left for left handed subjects) hand and fingers against a hori zontal stable surface (seat of chair or the like) For 6 seconds (same time as that used by *Iiberson et al* 1958) maximum static exercise was performed by the abductor of the small finger of the fixed hand Both members of each pair performed the exercise on each occasion

B *Isotonic concentric training*

The apparatus shown in Figs 3 and 4 was used for training and for measurement of the strength The recommendations of *DeLorme et al* (1951) were observed Before training was started once a week during the training period and at the end of the training 10 RM (Repetition

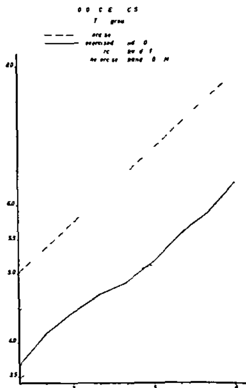


Fig 6
Survey of results of isotonic exercise Abscissa Duration of exercise in weeks Ordinate Mean strength for entire series (Units of strength see legend to Fig 3)

Maximum) was determined i e the resistance that could be overcome 10 times in succession but not more

At the beginning and end of the training period determinations were made of 1 RM in the experimental group i e the resistance that could be overcome once only At the same time measurements were made of 10 RM and 1 RM in the control group

The students worked in 5 subgroups of 8–9 selected at random

The daily exercises consisted of 10 contractions against the resistance 2 3 of 10 RM and 10 contractions against the resistance 1/1 10 RM

RESULTS

A *Isometric training*

The results are summarized in Fig 5 The mean strength of abduction of the small finger of the hand exercised was 1107 g (830 1530 g)

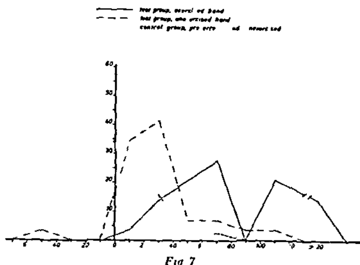


Fig 7

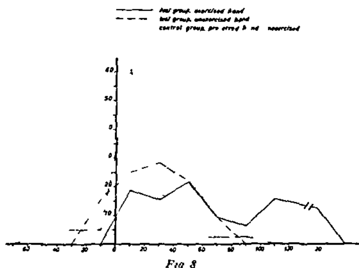


Fig 8

Figs 7-8

Result of isotonic exercise given in values for 10 RM and 1 RM Abscissa Percentage increase during 8 weeks exercise Ordinate Percentual distribution of material

before training After training the strength had increased by 216 ± 47 g corresponding to about 20 % In 2 cases there was an increase of 40 % and in 2 cases a decrease of 5 % and 13 % respectively The strength of the unexercised abductor of the small finger before training

was *on an average* 1126 g (850–1550 g). During training the strength increased by 106 ± 46 g corresponding to about 9 %.

In the control groups the initial values for the better hand was on the average 1117 g (850–1500 g) and for the other hand 1048 g (760–1620 g). During the experimental period the strength increased by 62 ± 33 g and 106 ± 44 g respectively.

Statistical analysis of the data showed that the increase in the strength of the muscle trained was significant. But the increase in strength of the abductor of the small finger of the untrained hand was not significant.

B. *Isotonic concentric exercise*

The results are summarized in Fig. 6 and in detail in Figs. 7 and 8. (Definition of units of strength is given in the legend to Fig. 3.)

I. *10 RM values* for the trained hand increased from 3.65 units (2.0–5.5) to 6.32 units (3.5–9.25), i.e. 2.67 units and 73 %. The difference was significant ($p < 1$ %). The corresponding values for the untrained hand were 3.48 units (2.0–5.0) to 4.50 units (2.25–7.0). The increase of 1.02 units corresponded to 29 % and was significant.

In the control group the values for the better hand increased from 4.11 (2.0–7.5) units to 4.30 (2.0–8.0) units, corresponding to 4 %. The increase was not significant.

II. *1 RM values* for the trained hand were at the beginning of the experiment on the average 5.0 (2.75–7.75) units and at the end 7.91 (4.0–11.0) units. The increase was 2.91 units, i.e. 58 % and was significant. The corresponding figures for the untrained hand were 4.47 (2.5–7.5) units to 5.52 (3.0–8.0) units, corresponding to 1.05 units and 23.5 %. This increase was also significant.

III. *Other observations*

a. A clear increase in strength was noted in all 5 subgroups but one group deviated remarkably from the remainder. The increase of the 10 RM values was 112, 84, 77, 74 and 30 %.

b. The following factors were studied and were not found to have any influence on the results of training:

1. Technical errors when the subject had become tired (pronation of the lower arm and/or ulnar abduction of wrist and/or lifting of elbow from support). Such errors were observed in 13 of the experimental groups.

2. A certain degree of absence from training. Nine of the experimental persons were absent 4–8 of the 40 exercises.

3. Inability to overcome resistance of 10 RM 10 times. Exactly half of the experimental persons could not overcome this resistance on 1–6 occasions and the remainder on 7–16 occasions.

c. The strength recorded was related to the breadth of the right femoral condyle (see *Lindegard* 1956). The dispersion of the values found for the experimental group was very wide. This argues strongly for the assumption that the subjects had not attained maximal strength of the trained muscle.

DISCUSSION

The students from both groups were healthy, they were of the same age and sex and all studying and training under uniform conditions. They had all received the same instructions. The training was standardized regarding apparatus, time of day and the influence of the director. It may therefore be assumed that both experimental groups and their controls were strictly comparable.

The fact that members of the isometric series could not, for practical reasons, use the apparatus for measuring strength during their training was considered to have little effect on the results.

All the persons partaking in the trial had been granted about a week to get accustomed to the apparatus, and the position of the hand during the trial was exactly the same as that which they had been instructed to assume during the preparatory period.

The remarkably poor increase in strength in one of the 5 subgroups of the isotonic concentric trial group suggests that small series can give misleading information and that such unmeasurable factors as team spirit of the group can influence the results.

The clearly better results noted for the isotonic concentric trial group compared with the isometric group (58–73 % against about 20 %) might be ascribed to the more favourable reaction of the motor units to isotonic concentric exercises *or* to the persons in the isometric group not having done the exercises in the proper way. The first possibility is denied by the results of *Hettinger et al.* (1953) and of *Liberson et al.* (1958).

In the isometric group the performance of the students was apparently relatively poor.

The protocols of the training offer no explanation for this poor cooperation. One might, however, imagine that the absence of movement

during training might mean an absence of valuable activating stimuli for some of the persons. The 10 RM test every week in the isotonic concentric group and the use of special equipment during training probably had a stimulating effect on the isometric group.

An incidental observation in the isotonic concentric group was a clear cross education, i.e. an increase in the strength of the M. abductor dig. V of the untrained hand.

CONCLUSION

If it is possible to choose between isometric muscle exercise according to *Hettinger et al.* (1953) and isotonic concentric exercise according to *DeLorme* (1945), the latter should be given preference, at least if the following conditions can be satisfied:

1. The subjects (patients) and assistants are given the opportunity of getting used to the equipment.
2. *The subjects (patients) perform most of the exercises with the help of friends (relatives).*
3. Muscle or muscle group is a mover.

SUMMARY

85 female physical therapy students were divided into two groups for investigation of the effect of exercise on the strength of Musculus abductor dig. V man. In one of the groups the subjects performed maximal isometric exercises for 6 seconds a day. In the other group training was done by the principles of *DeLorme* (1945) (isotonic concentric exercise against great resistance). In both groups the subjects trained 5 days a week for 8 weeks. The only stimulation was that they were reminded daily of the time of the exercise.

The isotonic concentric training produced an increase of strength by about 65 %, isometric training by about 20 %.

The difference between the results can probably be ascribed to the assumption that isometric method is less stimulating than the isotonic concentric procedure.

Isotonic concentric exercises are evidently preferable if the patient is left to himself to train the muscle.

82 physical therapy students served as controls.

RÉSUMÉ

85 étudiantes en thérapie physique ont été divisées en deux groupes afin d'étudier l'effet de l'exercice sur la force du muscle abducteur du petit doigt Dans l'un de ces groupes les sujets ont pratiqué des exercices isométriques maxima pendant 6 secondes chaque jour Dans l'autre groupe l'entraînement a eu lieu selon les principes de Delorme (1945) (exercice isotonique concentrique contre forte résistance) Dans leux deux groupes les sujets ont participé à l'entraînement 5 jours par semaine pendant 8 semaines La seule émulation a été le rappel chaque jour de l'heure de l'exercice

L'entraînement isotonique concentrique a provoqué une augmentation de la force d'environ 65 % l'entraînement isométrique d'environ 20 %

La différence entre les résultats doit être attribuée probablement au fait que la méthode isométrique n'offre pas le caractère d'émulation de la méthode isotonique concentrique

Il convient évidemment de choisir les exercices isotoniques concentriques s'il est laissé au malade seul le soin de procéder à l'entraînement du muscle

82 étudiants de thérapie physique ont servi de groupe de contrôle

ZUSAMMENFASSUNG

85 Studenten physikalischer Behandlung wurden in zwei Gruppen eingeteilt um die Wirkung von Übung auf die Stärke des musc abductor des 5 Fingers zu untersuchen In einer der Gruppen führten die Teilnehmer maximale isometrische Übungen für 6 Sekunden täglich aus In der anderen Gruppe wurden die Übungen gemäss den Prinzipien von De Lorme (1945) ausgeführt (Isotonisch konzentrische Übungen gegen grossen Widerstand) In beiden Gruppen übten die Teilnehmer 5 Tage wöchentlich während 8 Wochen Der einzige Antrieb war dass sie täglich an die Übungszeit erinnert wurden

Die isotonisch konzentrischen Übungen erzeugten eine Zunahme der Stärke um ungefähr 65 % die isometrischen Übungen um ungefähr 20 %

Die Verschiedenheit zwischen den Ergebnissen kann wahrscheinlich der Annahme zugeschrieben werden dass die isometrische Methode weniger stimulierend als das isotonisch konzentrische Vorgehen wirkt

Isotonisch konzentrische Übungen sind augenscheinlich vorzuziehen wenn der Patient beim Muskeltraining sich selbst überlassen ist 82 Studenten physikalischer Behandlung dienten als Kontrollen

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A UNIQUE HISTOLOGICAL FEATURE OF VITAMIN D RESISTANT RICKETS OBSERVED IN FOUR CASES[1]

By

H M Frost *M D* *

INTRODUCTION

In 1958 the writer reported a unique finding in a single case of so called vitamin D resistant rickets observed in fresh undecalcified un dehydrated bone sections made from tibias and fibulas of a boy who required corrective osteotomies for the deformities accompanying the disease (2) Since that time three additional cases have been examined two by us and one reported elsewhere by *Engfeldt Zetterstrom & Winberg* (1) All four cases reveal the same phenomenon suggesting that it is a unique feature of the disease and worthy of wider attention

The method of preparing the sections made from the material sub mitted from the Operating Room are reported in detail elsewhere and need be discussed only briefly here (3 4) In essence perfectly fresh hydrated unfixed unembedded sections are prepared by hand grinding under water or physiological saline on special carborundum surfaced sandpaper The cells in such sections are still living at the conclusion of the section making process if they were living at the beginning of it (3) The material is then stained in a basic fuchsin reagent the sur face stain ground off both sides (thus effectively clearing the sec tions) the section dehydrated and mounted in one of the standard re sins as a permanent mount

Sections prepared in this manner reveal cytology poorly However

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[1] Work supported by the following Grants A-4186 Surg National Institutes of Health Bethesda Md Orthopaedic Research and Education Foundation 293 Henry Ford Hospital

* Associate Orthopaedic Surgeon Department of Orthopaedic Surgery Henry Ford Hospital.

[3] Material from our three cases was generously submitted courtesy of Dr *Joseph Fleming*



Fig 1

Undecalcified cross section rib 22 year old woman 600 × basic fuchsin Wratten 58 The large circular density in the center of the figure is the Haversian canal seen parallel to its longitudinal axis The stained contents of the canal plus the filter used to obtain adequate contrast on the negative make the canal appear opaque The bone around the canal is for the most part transparent because it is unstained Around the Haversian canal are numerous osteocyte lacunae appearing as small oval densities Numerous canaliculae may be seen extending from the lacunae The canaliculae are 0 3 microns in diameter and connect the lacunae to the Haversian canal Note that the unstained bone extends right up to the lacunar walls The apparent diffuse darkening in the neighborhood of groups of canaliculae and lacunae is due to the presence of out-of focus structures of similar nature above and below the optical cut which comprises the illustration —At 10 00 o clock of the Haversian canal there is a patch of diffusely staining bone which is somewhat wedge shaped and slightly larger than the Haversian canal This is low density bone is a mineralization aberration and is termed feathering (5)

they reveal the structure of the bony substance containing the cells beautifully One of the peculiarities of such sections is that diffuse permeation of the mineralized bony substance occurs only when the mineralization is about 0 85 of the maximum observed in a unit volume

A UNIQUE HISTOLOGICAL FEATURE OF VITAMIN D RESISTANT RICKETS OBSERVED IN FOUR CASES[1]

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H M Frost M D[2]

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density bone The few instances in which peculiar perilacunar patterns of fuchsin demonstrable low density mineralization have appeared have been reported elsewhere (7) It is noteworthy that the pattern illustrated here has been observed *only* in material from cases of vitamin D resistant rickets See Fig 1

The case material will now be described briefly

CASE MATERIAL

1) I K a nine year old boy with vitamin D resistant rickets which is also present in the paternal background There was typical bowing of tibias fibulas and femurs typical widening and irregularity of the epiphyseal plates Typical untreated serum calcium 8 0 mg% serum

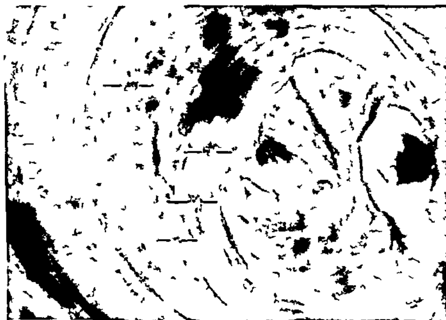


Fig 3

Undecalcified ection fr m the femur of A S referred to in the text Al ut 300 × Exactl the ame pattern is een as in Fig 2 At this higher magnifi ati n it is m re a fully appreci ted that there is a perilacunar halo due to diffu e fuchsin staining C ntrast the appearance f the e hal with the sharply lefined lacunae in Fig 1 At the right edge f the figure lies a Haver ian Canal Lining the wall of this canal i an te i l eam The eam appears in this figure mewhat like a layer of glass appli l to the Haversion canal wall—The India ink bars in all f the figures illustrate exemplars fuchsin stained perilacunar mineralization defects

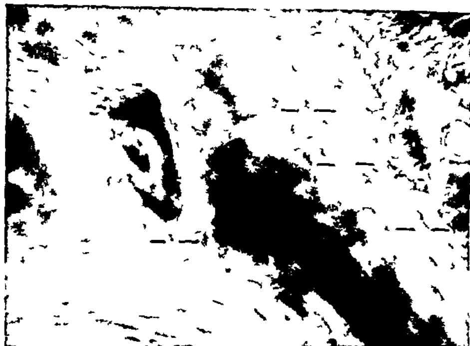


Fig 4
Section from R J referred to in the text The similarity of all three figures is striking In all three cases only about 30% of the lacunae exhibit the feature described the other 70% appearing normal with the techniques described

phosphate 1.5 mg % alkaline phosphatase 16 Bodansky units Received from 20 000 to 100 000 units of vitamin D per day No treatment for three months prior to surgery See Fig 2

2) A S an eight year old girl with a clinical and laboratory picture the same as in Case 1 There was no family history of the disease and all treatment was withheld for three months prior to surgery Treated with massive doses of vitamin D in the past See Fig 3

3) R J a five year old boy whose two siblings had the disease Clinical deformities serum calcium phosphate and alkaline phosphatase were similar to those in Case 1 and 2 All treatment was withheld for three months prior to surgery Treated with massive doses of vitamin D in the past and also with supplementary dietary phosphate See Fig 4

4) The fourth case is one published by *Engfeldt Zetterström & Winberg* (1) The microradiograph accompanying these authors article clearly reveals the perilacunar mineralization deficit already referred to

DISCUSSION

The peculiar morphological feature of these four cases is incomplete mineralization in the perilacunar bone, while inbetween lacunae mineralization density is higher.

This peculiar feature and its consistent and unique pattern suggest to the writer that there is some metabolic abnormality of the osteocyte residing in an affected lacuna. In theory, the result of this abnormality is that the osteocyte bathes itself in an extracellular fluid whose composition prevents full mineralization of the lacunar wall. Note that if the cause of the morphological feature being discussed were solely the abnormal serum concentrations of inorganic ions, *all* parts of the bone should be equally exposed to their effects, therefore equally affected, and a perilacunar locus would be incomprehensible.

In view of the interval of three months between last treatment with vitamin D and osteotomies in our three cases, it is unlikely that the feature discussed is caused by vitamin D.

A dozen cases of rickets and osteomalacia of other types in the files of the laboratory do not reveal the morphological phenomenon illustrated here, indicating that it is not merely a peculiarity of the rachitic or osteomalacic state in general.

It seems reasonable to propose that the histological feature described is characteristic only of so-called vitamin D resistant rickets, and might conceivably be of diagnostic significance and use.

SUMMARY

A perilacunar "halo" of low density bone has been observed around the osteocyte lacunae in undecalcified sections obtained from four cases of vitamin D resistant rickets, three being from Henry Ford Hospital Orthopaedic Research Laboratory and one previously reported by *Engfeldt, Zetterstrom & Winberg*. This feature and its pattern appear to be characteristic of and unique to this disease.

RÉSUMÉ

Un halo périlacunaire de basse densité osseuse a été observé autour de l'ostéocyte lacunaire dans une section non décalcifiée obtenue de quatre cas de rachitisme résistant aux vitamines D, trois venant du Laboratoire de recherches orthopédiques de l'Hôpital Henry Ford et un rapporté antérieurement par *Engfeldt, Zetterström & Winberg*. Ce phé-

nomène et la forme sous laquelle il se manifeste paraît etre caracteristique de cette maladie

ZUSAMMENFASSUNG

Eine perilakunäre Aufhellung von Knochen mit herabgesetzer Dichte wurde um die Osteocyten Lacunae in nichtentkalkten Schnitten von vier Fallen von Vitamin D resitenter Rachitis beobachtet Drei wurden am Henry Ford Hospital orthopädischen Forschungslaboratorium gesehen und einer wurde vorher von *Engfeldt, Zetterström & Winberg* veroffentlicht Diese Erscheinung und ihre Anordnung scheint charakteristisch und einzigartig fur diese Erkrankung zu sein

ACKNOWLEDGMENT

I wish to thank Dr *C J Mitchell* Mrs *Berthel Hentschel* and Miss *Elna Bosanko* for their help effort and patience in the preparation of this and other studies

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FROM THE CLINIC FOR ORTHOPAEDICS AND TRAUMATOLOGY, UNIVERSITY OF HELSINKI (HEAD: PROFESSOR K. E. KALLIO)

CUBITAL TUNNEL SYNDROME IN CUBITUS RECURVATUS

By

ERKKI KALLIO

It is well known that several conditions around the elbow joint can cause irritation to the ulnar nerve. Traumatic ulnar neuritis is the term most often used (*McCowan, Brooks* etc.). Tardy ulnar palsy is another common term (*Knight, Feindel & Stratford, Gay & Love* etc.). *Osborne* is in favour of "compression neuritis of the ulnar nerve". It is understandable that several terms have been used for this condition because of the many causes that may be behind it. Even the symptoms and signs differ to some extent. *Osborne, Feindel & Stratford* described cases where nothing pathological could be found but a normal anatomy was responsible for the symptoms. The aponeurotic arch overlying the nerve between the bony attachments to the olecranon and medial epicondyle of the two heads of the flexor carpi ulnaris muscle caused compression to the ulnar nerve. They coined the term "cubital tunnel" and an analogy to the carpal tunnel syndrome comes to mind. The nerve palsy resulted from gradual compression especially when flexing the elbow. It was not due to traction or friction in the ulnar groove which has been the common explanation for delayed ulnar paralysis.

Osborne classifies the causes of ulnar neuritis at the level of the elbow as follows: 1. Arthritis (osteoarthritis, osteochondritis dissecans with secondary arthritis, rheumatoid arthritis, tuberculous arthritis, neuropathic arthritis secondary to syringomyelia). 2. Old fracture (malunion of medial epicondylar fracture with deformity of groove, supracondylar fracture with malunion and late arthritis, cubitus valgus due to old separated capitellar epiphysis—the classical 'tardy ulnar palsy'). 3. Ganglia (arising from medial capsule of elbow joint or deep in fibres of flexor carpi ulnaris). 4. Local injuries to the post-condylar

groove (causing scarring and constriction of nerve). 5. Idiopathic (This group comprises more than 10 per cent of causes of ulnar neuritis and is due to simple compression by the fibrous bridge of flexor carpi ulnaris. Although the elbow joint is normal on physical and radiological examination, some swelling of the ulnar nerve in the post-condylar groove is present in most of the cases.)

Apart from causes mentioned above, hypermobility of the nerve, recurrent ulnar nerve dislocation at the elbow have also been shown to produce symptoms (*Childress, Osborne*). *Childress* reports observations and treatment of thirty four patients with ulnar neuritis due directly or indirectly to excessive nerve mobility. Only seven of the patients *required surgical transplantation. All these 34 patients had* precipitating injury before they got ulnar neuritis. He also examined 2000 supposedly normal elbows with no signs of ulnar neuritis and found 121 cases with incomplete dislocation and 41 cases with complete dislocation of the nerve. Not one of these 162 persons with dislocating ulnar nerves knew that he had such an anomaly. It is stated that the hypermobile ulnar nerve is considerably more exposed to injury. *Palkki & Vainio* described 18 cases of compression neuritis of the ulnar nerve where rheumatoid arthritis was responsible for the symptoms. Wasting of the intrinsic muscles was of no diagnostic value in those cases.

The present writer may add to the syndrome in question a case of bilateral tardy ulnar nerve palsy due to compression of the ulnar nerve in the cubital tunnel, where the patient had hypermobile elbow joints, cubitus recurvatus, which probably contributed to the development of symptoms.

A male orderly, twenty five years old had since birth had hypermobile elbow joints. There is no history of injury to the upper limbs. The range of active movements in both elbow joints was normal in all other aspects than the (hyper-) extension-flexion range, which was 205–30 degress on the left side and 200–30 degrees on the right side (Fig. 1). There was no valgus or varus position and the carrying angle was 165 degrees on the right and 170 degrees on the left elbow. No abnormality could be detected on radiological examination. The patient complained of aching pain in the left hand for about three months duration. He also noted some tenderness around the ulnar side of the left elbow. There was clear hypaesthesia in the ulnar distribution of the left hand. Weakness in all the intrinsic muscles of the hand was present. Flexor carpi ulnaris worked well but flexor digitorum profundus to the little



Fig 1
Pre operative appearance of one of the elbows
(Both sides were similar in inspection)

and ring fingers showed some weakness The typical clawed appearance was seen in the little and ring fingers and to some extent also in the middle finger (Fig 2) There were similar symptoms and signs also in the right hand but they were much weaker and did not disturb him when he was first seen

The left ulnar nerve was explored at the elbow It was easy to see that the nerve was compressed against a band of fibrous tissue bridging



Fig 2
Pre operative clawing of the fingers in the right hand
(The left hand was similar)

groove (causing scarring and constriction of nerve) 5 Idiopathic (This group comprises more than 10 per cent of causes of ulnar neuritis and is due to simple compression by the fibrous bridge of flexor carpi ulnaris Although the elbow joint is normal on physical and radiological examination some swelling of the ulnar nerve in the post condylar groove is present in most of the cases)

Apart from causes mentioned above hypermobility of the nerve recurrent ulnar nerve dislocation at the elbow have also been shown to produce symptoms (*Childress, Osborne*) *Childress* reports observations and treatment of thirty four patients with ulnar neuritis due directly or indirectly to excessive nerve mobility Only seven of the patients required surgical transplantation *All these 34 patients had* precipitating injury before they got ulnar neuritis He also examined 2000 supposedly normal elbows with no signs of ulnar neuritis and found 121 cases with incomplete dislocation and 41 cases with complete dislocation of the nerve Not one of these 162 persons with dislocating ulnar nerves knew that he had such an anomaly It is stated that the hypermobile ulnar nerve is considerably more exposed to injury *Pulkki & Vainio* described 18 cases of compression neuritis of the ulnar nerve where rheumatoid arthritis was responsible for the symptoms Wasting of the intrinsic muscles was of no diagnostic value in those cases

The present writer may add to the syndrome in question a case of bilateral tardy ulnar nerve palsy due to compression of the ulnar nerve in the cubital tunnel where the patient had hypermobile elbow joints cubitus recurvatus which probably contributed to the development of symptoms

A male orderly twenty five years old had since birth had hypermobile elbow joints *There is no history of injury to the upper limbs* The range of active movements in both elbow joints was normal in all other aspects than the (hyper) extension flexion range which was 205 30 degress on the left side and 200 30 degrees on the right side (Fig 1) There was no valgus or varus position and the carrying angle was 165 degrees on the right and 170 degrees on the left elbow No abnormality could be detected on radiological examination The patient complained of aching pain in the left hand for about three months duration He also noted some tenderness around the ulnar side of the left elbow There was clear hypaesthesia in the ulnar distribution of the left hand Weakness in all the intrinsic muscles of the hand was present Flexor carpi ulnaris worked well but flexor digitorum profundus to the little

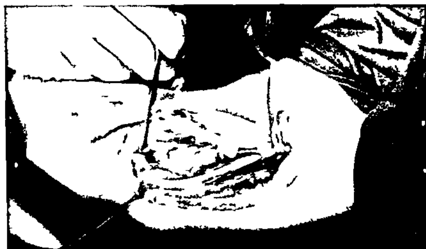


Fig 3

The right ulnar nerve explored at the elbow The fibrous bridge responsible for compressing the nerve can be seen between the two hooks

flexor origin The immediate postoperative result was good The patient could actively extend all the fingers (Fig 4) There was no pain and no sensory disturbance Six weeks later the patient gradually incurred pain in the elbow area and some clawing of the fingers seemed to recur The nerve was re explored and found twisted distally over the fibrous edge of flexor carpi ulnaris The fibrous edge was divided The postoperative result was satisfactory for some weeks but then gradually deteriorated again Weakness in the ulnar intrinsic muscles increased and hypaesthesia developed in the ulnar sensory distribution



Fig 4

Immediate postoperative result The clawing of fingers has disappeared

of the right hand. Another re-exploration was performed and gross scarring of the muscular bed was seen and an amount of fibrosis was noted in the ulnar nerve trunk. Neurolysis was performed along a distance of about 8 centimetres. After this operation the muscles innervated by the right ulnar nerve have gradually developed some more power and the area of sensory disturbance has somewhat diminished. The patient has not complained of pain.

This case seems to fit to the cubital tunnel syndrome described by *Osborne* and *Feindel & Stratford*. The hypermobility in the extension range probably contributed to the development of symptoms by causing secondary hypermobility to the ulnar nerve especially in heavy manual work. The intramuscular placement operation to the left ulnar nerve which caused more symptoms was very successful. It was interesting to note that the symptoms, even the clawing of fingers, disappeared immediately. The deep intramuscular placement operation on the right side did not succeed so well. There could have been some technical faults. Although the nerve became free in the first instance it had some secondary kinking later. The question arises whether it would not have been better to perform only the decompression operation described by *Osborne*. Considering the anterior transposition of ulnar nerve *Osborne* writes: "Even with a correct surgical technic, however, the results of transposition are sometimes unpredictable. Residual tenderness and causalgic pain may occur and gross scarring of the muscular bed may cause further damage to the nerve. The operation is not a small procedure and in the past surgeons have hesitated to explore and transpose the nerve until clinical signs were present and a definite diagnosis possible." He also states that the results of the minor decompression procedure appear to be as satisfactory as the results after the more elaborate operation of anterior transposition. It might have been sufficient to do just the decompression operation in the present case too.

There are different opinions in the transposition technic. *Knight* and *Lange* advocate a subcutaneous placement of the nerve. *Brooks*, *Childress*, *McGowan* and *Osborne* are in favour of the deep intramuscular placement where the nerve will lie between the common flexor origin and brachialis muscle next to the median nerve on the brachialis. Although *Childress* and *Osborne* recommend the deep intramuscular placement they do not point out that the nerve should be deep to the common flexor origin. In the present case the successful transposition was performed to a intramuscular channel prepared between flexor carpi ulnaris and the other flexors. On the other elbow of the present

case the nerve was transferred deep to the common flexor origin with less success

The question of traumatic ulnar neuritis is not a simple one The lesion can be due to compression friction or traction It can be caused in the ulnar groove of the medial humeral epicondyle or anterior or distal to the groove If flexor carpi ulnaris and flexor digitorum profundus to the little and ring fingers are not affected or there are no sensory disturbances it may be difficult to find out where the lesion is The pathology can of course be in the wrist or hand or even in the neck region Careful clinical examination should in most cases show the site of the lesion

It is interesting that even in the absence of any gross pathology around the elbow traumatic neuritis of the ulnar nerve can exist at that area The disappearance of the clawing of the fingers immediately after the operation was surprising

SUMMARY

The author describes a case of bilateral traumatic ulnar neuritis due to repeated gradual compression to the nerve trunk in the cubital tunnel By the term cubital tunnel is meant the structure distal to the ulnar groove where the nerve emerges to the submuscular channel formed by flexor carpi ulnaris aponeurosis and the medial ligament of the elbow joint Hypermobility of the elbow in the extension flexion range in this case probably contributed to the development of symptoms The symptoms totally disappeared on one side and diminished on the other side after deep intramuscular placement of the ulnar nerve It was surprising that the clawing of fingers disappeared immediately after operation

RESUME

L auteur decrit un cas de neurite ulnaire traumatique bilaterale due a une compression repetee sur le tronc du nerf du tunnel cubital Par « tunnel cubital » on pense a la structure distale du sillon ulnaire ou le nerf emerge pour passer au canal submusculaire formé par l aponevrose du flechisseur carpien ulnaire et le ligament medial de l articulation du coude L hypermobilite du coudre par rapport a l extension et a la flexion contribue probablement dans ces cas a l accroissement des symptomes Les symptomes disparaissent entièrement d un cote et diminuent de l autre apres le placement intramusculaire profond du

nerf ulnaire Il a été surprenant de constater que la position crochue des doigts a disparu immédiatement après l'opération

ZUSAMMENFASSUNG

Der Verfasser beschreibt einen Fall von doppelseitiger traumatischer Neuritis des N ulnaris die durch wiederholte allmähliche Kompression des Nerven im Ellbogenkanal hervorgerufen wurde Unter dem Ausdruck Ellbogenkanal versteht man die Struktur distal vom sulcus ulnaris wo der Nerv in den submuskulären Kanal eintritt der von der Aponeurose des Flexor carpi ulnaris und dem medialen Ligament des *Ellbogengelenkes gebildet wird Überbeweglichkeit des Ellbogens im* Streck und Beugungsbereich haben in diesem Falle wahrscheinlich zur Entwicklung der Symptome beigetragen Die Symptome verschwanden vollständig auf einer und verringerten sich auf der anderen Seite nach tiefer intramuskulärer Verlegung des N ulnaris Es war überraschend dass die Klauenstellung der Finger unmittelbar nach der Operation verschwand

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FROM THE ORTHOPAEDIC HOSPITAL, COPENHAGEN

TREATMENT OF NON-UNITED NAVICULAR FRACTURES BY TOTAL EXCISION OF THE BONE AND THE INSERTION OF ACRYLIC PROSTHESES

By

OLAF AGNER

In spite of the appearance of new methods of treatment in the most recent decades and the improvement of the diagnostic aids, especially X-ray diagnosis, defective healing of navicular fractures is no rarity. If not treated the fracture forms a pseudarthrosis which usually by degrees becomes painful and results in reduced strength in the hand, limitation of mobility and possibly deformity of the wrist joint. In these cases deforming arthritis is very often found in the radiocarpal joint on X-ray examination.

In 1920–30 *Bohler* and *Schnek* showed that navicular fractures can be healed by conservative treatment with plaster splint when the immobilisation is effective and is maintained for a sufficient time. This is confirmed by numerous authors and there is now wide agreement that the treatment of fresh navicular fractures ought to be conservative. The incidence of fracture healing is stated to attain 80–95 % with an average treatment period of 8–10 weeks (*Bohler* 96 %, *Soto Hall* 95 %, *Couble* 96 %, *Troyan* 96.4 %, *Watson Jones* 95 %, *Stewart* 98 %, *Luck* 95 %). Other authors however found somewhat lower incidence: *Aleman* 74 %, *Rehbein* 78 %, and *Barr* discovered that 26 % of the navicular fractures were not healed in spite of apparently adequate treatment. *Cutler* estimates that "failure of union is found in 30–40 % of all navicular fractures".

Old non-united navicular fractures present a difficult therapeutic problem. In the comprehensive literature on the subject considerable divergencies of opinion exist as to which methods of treatment, from the most conservative to the most actively surgical, should be chosen. Among these methods the following may be mentioned:

Prolonged immobilisation (*Bohler, Schnek, Rehbein, Duben & Gelbke, Troyan, Jahna*).

Beck drilling (*Schnek Obletz & Halbstein, Andersen & Therkelsen Solo Hall*)
Internal fixation with metal pin (*Geissendorfer Giesecking Lindwall*)
Internal fixation with bone graft (*Adams & Leonard Murray Armstrong Palmer & Walden Cobey & White*)
Transplantation of cancellous bone (*Malti Russe*)
Intercarpal arthrodesis (between the navicular and lunatum) (*Thornton*)
Radiocarpal arthrodesis (*Smith Petersen*)
Radial styloidectomy (*Barnard & Stubbins Lyman Smith*)
Bentzon s interposition method (*Bentzon Randlov, Percy Bertelsen*)
Excision of proximal carpal row (*Brittain Stack, Speed*)
Partial excision of the fragments (*Aleman Solo Hall Watson Jones Downing*)
Total excision of navicular (*Hirsch Ritter, Davidson & Horwitz Dwyer*)
Insertion of prosthesis vitallium or acrylic after total excision of the navicular (*Metcalfe Legge, Waugh & Reuling Picaud Merle d Aubigne*)

It is not the purpose of this study to determine which method produces the best result For this large series of cases are required directly comparable but treated according to each individual method and investigated after a long period of observation This can hardly be carried out on the basis of the literature available at present

At the Orthopaedic Hospital in Copenhagen the treatment of old and non united navicular fractures has developed since 1934 as follows

Plaster cast when cysts are present indicating reactive processes
Removal of the proximal fragment in true pseudarthroses if this is sclerosed and forms less than 1/3 of the bone
Bentzons interposition operation with wide fracture lines
Radiocarpal arthrodesis when deforming arthrosis is present

However after following up a series of 243 patients with fracture of the os naviculare we found a small group which had been treated by insertion of prosthesis after total excision of the navicular a method which has produced good results according to the literature Since this could not be confirmed by our follow up investigation we thought it would be of interest to publish this as we believe our results to be a warning against this method

TABLE I

Case	Sex	Age	Occupation	Initial treatment	Time from accident to operation	Primary result	Final result	Later treatment	Complication
1	m	17	worker	Open reduction of semilunar. Plaster cast 12 weeks	7 months	bad	bad	Arthrodesis 10 months after the operation	Dislocation of semilunar
	m	0	farmer	Plaster cast 6 weeks	8 months	bad	bad	Arthrodesis 3 years after the operation	Dislocation of semilunar
3	f	40	waiter	Plaster cast 17 weeks	6 months	bad	bad	Arthrodesis 1½ years after the operation	Arthritis
4	m	33	worker	Plaster cast 8 weeks	?	bad	bad	Arthrodesis 2¾ years after the operation	Comminuted fracture Arthritis
5	m	28	worker	Plaster cast 4 weeks After 2 years drilling	10 years	fair	bad	Arthrodesis 2 years after the operation	
6	m	7	sailor	Plaster cast 11 months	½ years	fair	fair		Arthritis
7	m	18	clerk	Plaster cast 21 weeks	½ years	good	good		

Total excision of the naviculare was declared by *Hirsch* who gave an account of his first results in 1914. 9 patients were operated on, all with good results. Full working capacity was achieved after an average period of 6 weeks. In later studies *Hirsch* states that the long term results are good. According to *Hirsch* the operation should be undertaken as early as possible, if possible as soon as the fracture is diagnosed and *before arthritis arises in the joints.* Moreover the *importance of the* following points is emphasised: that the whole of the os naviculare is removed, that nothing is left, and that the operation is executed so as to avoid damaging neighbouring cartilage.

Ritter (1929) prefers excision of the one fragment, when this is dislocated, but believes it necessary to remove both fragments in order to achieve good function of the wrist joint when the fracture "has existed some time without being recognised and consequently no attempt at reduction has been made."

In 1938 *Davidson & Horwitz* published 7 cases treated by total excision of the naviculare. Pre-operative X-rays showed pseudarthroses in all cases. The observation period following the operation was from 1–15 years. In 5 cases the results were excellent anatomically and functionally; in 2 cases there was moderate limitation of mobility but no pain. These two were designated as good. *D. & H.* think that the total excision ought to be chosen in 1) fractures which cannot be reduced even in open reduction, 2) severely comminuted fractures, especially when they are caused by other injuries in the wrist joint, e.g. dislocation of the lunate bone, and 3) neglected cases with pronounced and irreparable degeneration of the fragments.

Dwyer in 1949 presented the largest series. 19 patients were followed up. In 12 cases the result was found to be "good", in 4 "fair", and in 3 cases "bad". *Dwyer* points out that the results become worse when *arthritis is present and with subluxation of the lunate bone.* In some cases progressive dislocation forward of the os lunatum was found on late X-ray control. Radial deviation of the hand was not observed. Mobility in the wrist joint improved in 15 patients — maximal recovery sometimes took a year or more.

Many authors have advised against the total excision of the naviculare (*Böhler, Schnek, Stewart, Aleman, Obletz & Halbstein, Troyan, Duben & Gelbke*). They consider that the naviculare is so important for the structure of the hand that its removal will always bring about damage to the wrist joint which will go into radial abduction, that function becomes steadily worse even if some improvement can be obtained im-

mediately after operation This experience brought total excision of the navicular into discredit in most hospitals —in recent years however the operation has been adopted again by some surgeons who recognising the importance of the os naviculare for the stability of the hand replaced the navicular by a prosthesis

Metcalfe Legge Waugh & Reuling have used vitallium as a prosthesis material *Picaud* and *Merle d'Aubigne* acryl

Metcalfe operated on 30 patients all with good results One patient was observed for 3½ years owing to reflex dystrophia but the end result was good

Legge 7 cases all good *Waugh & Reuling* 3 cases 2 good 1 less good

Picaud inserted acryl in one case with good results *Merle d Aubigne & Ramadier* had 2 cases with acryl the one with good and the other with poor results

The above mentioned authors point out the advantages of the method to be 1) relieving of the pain in the wrist joint 2) a functionally effective wrist joint 3) short period of treatment

In the series published however primary results are involved *Merle d Aubigne* gives no information about observation time *Picaud* s single patient was able to return to work after 2 weeks *Legge* s 7 patients after between 3 weeks to 2 months but in none of these authors does one find information about follow up investigations As already stated *Metcalfe* observed one patient for 3½ years but gives no information about a follow up of the remaining 29

Waugh & Reuling followed up their patients (3) for 7 1a and 16 months respectively after the operation and conclude "The use of vitallium replica for replacement after excision of the fragments of an ununited fracture of the carpal scaphoid is in the experimental stage While the results to date are encouraging sufficient length of time has not elapsed to determine whether or not the use of these vitallium replica will be of value in solving the problem of the ununited fracture of the carpal scaphoid

Even if provisional information about a new operation technique is naturally of importance one must however require a thorough post operative investigation into all the cases operated on and a long observation period—10 1a years presumably—in order to determine the value of such a method Several authors have also expressed their scepticism

In 19)9 Troyan stated substitution operations for navicular frac

tures are still very new and only the future can show how the late results will be.

The follow up investigations of *Busch, Bing & Hart Hansen* in 1948, of *Henrichsen, Jansen & Krogh Poulsen* in 1952 and of *Collins* in 1954 showed that acryl is tolerated to a considerable degree by the tissues. *Newman & Scales* in 1951 and *Scales* in 1956 showed that no tissue reaction was seen when implanting acryl into the muscles of animals; if however the substance was exposed to mechanical forces, especially wearing forces, tissue reaction was seen in form of fibrosis.

As far as vitallium is concerned *Speed* remarks that even if a prosthesis of this material is smooth on the surface this does not hinder the formation of fibrous tissue around such a surface which will gradually narrow the natural gap left by the removal of the bone and thus possibly prevent movement to a normal extent.

Venables points out that the mechanical conditions for a navicular prosthesis are quite different from those for a prosthesis in the hip joint where alloplastics especially have been utilised, and that similar conclusions cannot be drawn. In the hip joint the prosthesis is stabilised, it is present in order to stabilise the joint and takes part in its functions. In contrast to this the navicular prosthesis is applied to a stabilised area, function occurs around the prosthesis, while it is immobile itself.

We have no experience of navicular prostheses of vitallium. On the other hand acrylic prostheses have been used in 7 cases on the initiative of *Sven Kiaer* in Dept. 2 of the Orthopaedic Hospital, Copenhagen. The operations were carried out in the years 1950–52.

All patients had pain in the wrist joint, limited mobility and reduced strength in the hand. 5 had hard work, 2 had lighter work. 3 fractures were in the left wrist, 4 in the right wrist joint. In 1 case the fractures had existed for 10 years, in 2 cases for 2½ years, in 3 cases 6, 7 and 8 months respectively. In 1 case the patient had suffered an accident 3 months before the operation and swelling of the wrist joint. On X-ray examination, however, a well developed pseudarthrosis was found with sclerosis of the fracture ends and initial arthrosis in the radiocarpal joint indicating that the original trauma must be sought several years back. In 2 cases in addition to navicular fractures dislocation of the lunate bone was found (1, 2). 1 fracture was comminuted with 3 irregular fragments (4), the others were transverse fractures near the centre of the bone. In 3 cases arthritis was found before the operation (3, 4, 6).

Operative technique: the operation was carried out in 2 parts. 1) The navicular bone was removed through a dorsoradial incision, an impression of the cavity was taken with a plastic mass and the wound was closed. 2) 1 to 2 days afterward (in case 2, however, 9 days after) the wound was opened again and the prosthesis was inserted. A plaster cast was applied for 3 weeks; afterwards the hand was given physiotherapy.

In cases 1–4 there was constant pain and swelling of the wrist joint—the mobility was improved immediately after the operation but became gradually severely limited. None of these patients became fit for work. Case 5 could begin to work 4 months after the operation; he only had slight pain and for a short period better mobility than before. 1 year afterwards the mobility was severely limited, there was increasing reduced strength and also swelling of the hand. In these 5 cases the prosthesis was removed and arthrodesis was performed. In each case pronounced fibrosis was found around the prosthesis with thickening of the joint capsule and severe arthritis in the radiocarpal joint.

The prosthesis was not removed in only 2 cases. Case 6 works as a seaman. He has no pain but yet makes use of a wrist joint capsule. Upon the follow up 10½ years after the operation the joint was found to be slightly deformed, the hand was in radial deviation and the prosthesis was prominent dorsally. The mobility in the damaged right wrist joint is half that in the left and the strength of the hand is reduced. The X-ray examination shows a severely deforming arthritis both in the radiocarpal and in the intercarpal joints.

In case 7 the result is good. He works as a clerk and uses a typewriter without pain. Mobility is only slightly limited, the strength of the hand slightly reduced. There is no deformity. X-rays 10 years after operation show good distance between the neighbouring bones. As a sign of initial arthritis there is slight tapering of the radial styloid process while otherwise conditions are the same as directly after the operation.

The results of the 7 substitution operations have thus produced satisfactory results in one case only after 10 years observation. In another case the clinical results was fair, but the X-ray showed severely deforming arthritis. In 5 cases arthrodesis had to be performed after ½–3 years.

There is scarcely any doubt that the mechanical conditions pointed out by *Venable* had a decisive importance in the poor result. A navi-

cular prosthesis is an unattached foreign body in a preshaped cavity and is not like the navicular bone fixed by ligaments. A foreign body reaction must be expected both when using vitallium and acryl and this leads to the formation of fibrous tissue around the whole prosthesis resulting in limited mobility. Moreover with acryl prostheses "wearing" *occurs producing increased tissue reaction according to Scales.* This is confirmed by this investigation since 2 of the 3 patients who went back to their work had hard work and severe deforming changes in the wrist joint resulted, while the 3rd patient who had easy work avoided these changes.

SUMMARY

A series of 7 cases of nonunited navicular fractures was treated by excision of the fragments and insertion of an acrylic prosthesis. The series was followed up 9–11 years after operation.

In all 7 cases primary improvement of the wrist joint's mobility was obtained. 4 patients remained however unfit for work owing to pain. 1 patient was able to return to work after 4 months but a year after the operation the mobility of the wrist joint was severely limited, there was pain, reduced strength and swelling of the wrist joint. In these 5 cases the prosthesis was removed ½–3 years after the operation and radiocarpal arthrodesis was performed. It was only in 2 cases that the prosthesis was not removed — 10 years after operation one of these has severely deforming arthritis in the radiocarpal joint but no pain, while the other has a good result. Radiologically only a slight arthritis can be found in this patient.

Thus the results of the 7 substitution operations were only satisfactory in one case.

The mechanical conditions for a navicular prosthesis have an important influence on the poor result, since the prosthesis is a loose foreign body in a preshaped cavity and a foreign body reaction must be expected. In addition although acryl has proved in experimental research that it is tolerated by the tissues, this substance provokes a powerful tissue reaction in the form of fibrosis when it is exposed to mechanical forces, especially wearing forces.

RÉSUMÉ

Une série de 7 cas de fractures du scaphoïde traités par excision des fragments et mise en place d'une prothèse acrylique ont été réexaminés entre 9 et 11 ans après l'opération.

Chez tous les 7 on a observé une amélioration primaire de la mobilité du poignet. Toutefois 4 malades n'ont pas retrouvé leur capacité de travail en raison de douleurs. Un malade avait pu reprendre son travail au bout de 4 mois, mais un an après l'opération la mobilité du poignet était fortement réduite: il y avait des douleurs, une diminution de la force et une enflure du poignet. Dans ces 5 cas la prothèse avait été enlevée entre 6 mois et 3 ans après l'opération et l'on avait pratiqué l'arthrodèse radio-carpienne. Dans deux cas seulement la prothèse n'a pas été enlevée. L'un avait 10 ans après l'opération une arthrose déformante prononcée dans l'articulation radio-carpienne, mais pas de douleur, tandis que chez l'autre le résultat était bon. A la radiographie on n'a trouvé chez ces malades qu'une légère arthrose.

Ainsi c'est seulement dans un cas que les résultats de cette opération de substitution ont été satisfaisants.

Les facteurs qui entrent en considération par rapport aux mauvais résultats obtenus sont les conditions mécaniques d'une prothèse du scaphoïde qui est un corps étranger introduit sans fixation dans une cavité préformée. Il faut s'attendre à une réaction au corps étranger. A cela s'ajoute que bien que les tissus tolèrent la résine acrylique, l'usure particulière de cette matière lorsqu'elle exposée à des effets mécaniques provoque une forte réaction des tissus sous forme de fibrose.

ZUSAMMENFASSUNG

Eine Reihe von 7 Fällen nicht geheilter Kahnbeinbrüche wurde mittels Excision der Fragmente und Einsetzung einer Akrylprothese behandelt und 9–11 Jahre nach der Operation nachuntersucht. Bei allen erreichte man primär eine Besserung der Beweglichkeit des Handgelenkes. 4 Patienten wurden jedoch nicht arbeitsfähig wegen Schmerzen. 1 Patient konnte seine Arbeit nach 4 Monaten wiederaufnehmen, ein Jahr nach der Operation war jedoch die Beweglichkeit im Handgelenk stark eingeschränkt. Es bestanden Schmerzen, herabgesetzte Kraft und Schwellung des Handgelenkes. In diesen 5 Fällen wurde die Prothese ½–3 Jahre nach der Operation entfernt und eine radio-carpal Arthrodese vorgenommen. Nur in zwei Fällen wurde die Prothese nicht ent-



Fig 2

Noticeable swelling in the dorsum of the left foot This case was first regarded as a marching fracture

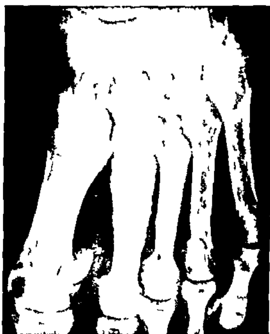


Fig 3

There is reactive thickening and densification in the shaft of the second metatarsal The nidus is totally overshadowed by bone sclerosis



Fig 4
In the tomograhy one may suspect a nidus at the base f the second metatarsal bone

considerably after walking There was marked tenderness at the base of the second metatarsal and noticeable swelling in the dorsum of the left foot (Fig 2) Weight bearing especially standing on toes was painful Aspirin relieved the pain and the patient had used it considerably An ordinary radi graph sh wed only periosteal new b ne formation and the thickened cortex overshadowed the partly ossified ni lus even in tom graphy (Fig 3 and Fig 4)

A tentative diagnosis of osteoid teoma was ma le and the maximal tender part was explored When the cortex was opened a compact bright red osseous nidus the size of a small pea was clearly seen delimite l from the neighbouring bone by a narrow zone The hist l gical changes were typical t osteoid osteoma The pain and soreness di appeared after this nidus had l een removed with some amount of surroun ling bone The patient has b en symptom free now for al ut three months

These two cases were osteoid osteom is The diagnosis escaped re cognition for some time probably because of lack of experience of its radiographic features The hypertrophied cortex had obscured the pri mary lesion The clinical symptoms were somewhat overshadowed by signs from the adjacent joint Metacarpal and metatarsal bones are

probably rare spots for osteoid osteoma since relatively few cases have been reported in literature so far (*Carroll Freiberger et al Golding Moberg*) *Bergstrand* had already described one case in 1930 although it was not entitled as osteoid osteoma at that time The diagnosis of an old marching fracture had been suggested in one of Golding's cases *Spence & Lloyd Roberts* draw attention to a problem of differential diagnosis between tuberculosis of a joint and an osteoid osteoma close to a joint They were the first to mention regional osteoporosis as a feature in osteoid osteoma

The main lesions which can be confused with osteoid osteoma are solitary enostosis localised cortical bone abscess sclerosing osteitis syphilis of bone Ewing's tumor in the early stages and glomus tumour (*Barnes, Carroll, Jaffe Purcell et al*, and others) The diagnosis of osteoid osteoma should not produce much difficulties in most cases if the main features of it are kept in mind It causes pain often not distinctly localised and disproportionate to the size of the lesion There is marked local tenderness which is a good guide to the central nidus There might be some swelling and symptoms from adjacent joints It appears usually in children or young adults There is no fever and the blood picture is normal Aspirin relieves the pain The radiological changes are twofold those of the osteoid osteoma proper the nidus and those incited in the surrounding osseous tissue The reactive cortical thickening and sclerosis can be very striking so that it may be difficult to distinguish the osteoid osteoma even in a tomograph In positive cases the operation should always bring a clearly defined nidus into view The histopathology of the condition should not present difficulties to an experienced examiner The removal of the nidus cures the condition If the pain is not severe one may wait for spontaneous clinical arrest which is likely to occur in a few years

SUMMARY

The writer describes two cases of osteoid osteoma one in the metacarpal and one in the metatarsal bones The former escaped recognition for two years and the latter for one year In both cases there was marked reaction in the surrounding osseous tissue which almost obscured the nidus in the radiograph Signs from adjacent joints confused the condition which was first regarded as tuberculosis in the former and marching fracture in the latter case Surgical exposure revealed a

typical osteoid osteoma which was confirmed by histological examination The symptoms were relieved immediately by excising the nidus

RESUME

L auteur decrit deux cas d osteome osteoide l un dans les metacarpiens l autre dans les os metatarsiens Le premier a echappe a l attention pendant deux ans l autre pendant un an Dans les deux cas il y avait une reaction marquee dans les tissus osseux environnants qui avait pour ainsi dire assombri le nid sur la radiographie Des signes dans les articulations adjacentes ont semé la confusion sur ces cas consideres d abord chez le premier comme une tuberculose chez le second comme une fracture de la marche L operation revela un osteome ostéoide typique confirme par l examen histologique Les symptomes se trouverent immediatement soulages par l excision du nid

ZUSAMMENFASSUNG

Der Verfasser beschreibt zwei Fälle von osteoidem Osteom eines im Mittelhand und das andere im Mittelfussknochen Das erstere wurde erst nach zwei Jahren das letztere nach einem Jahr entdeckt In beiden Fallen fand sich eine beachtliche Reaktion im umgebenden knöchernen Gewebe die im Rontgenbild fast den Herd verschattete Symptome von den benachbarten Gelenken verschleierten den Zustand der im ersteren Falle zunächst als Tuberkulose und im letzteren als Marschfraktur angesehen wurde Die Freilegung durch den Chirurgen zeigte ein typisches osteoides Osteom was auch durch die histologische Untersuchung bestatigt wurde Durch die Exzision des Herdes wurden die Symptome sofort beseitigt

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FROM SOPHIES MINDE OSLO UNIVERSITY ORTHOPAEDIC HOSPITAL
(HEAD PROF DR MED IVAR ALVIK)

ARTHRODESIS AND ARTHROPLASTY OF THE HIP JOINT

By

IVAR ALVIK

Osteoarthritis and severe posttraumatic conditions such as necrosis of the femoral head and pseudarthrosis of the neck are in most cases so disabling that surgical intervention has to be done to reduce pain and to restore physical fitnes and working ability The surgical procedures are legion ranging from excision of the femoral head (*Kocher Girdlestone*) denervation of the joint (*Tavernier*) different types of reconstruction operations (*Whitman Colonna*) osteotomies (*Lorenz Pauwels McMurrey Brittain*) muscle release operation (*Voss McFarland*) to arthrodesis and many different types of arthroplasties
cup arthroplasty (*Smith Petersen*) skin arthroplasty (*Kallio*) plastic head replacement arthroplasty (*Judet*) and various types of intramedullary replacement arthroplasty (*Thompson Moore*)

For old and debilitant individuals with a very painful hip lesion we consider the Girdlestone operation to be of great value when arthrodesis or arthroplasty is contraindicated We do not have any experience with osteotomies for osteoarthritis of the hip and apart from a few cases of Girdlestone operation arthrodesis and arthroplasty have been the main surgical procedures for osteoarthritis severe posttraumatic conditions and congenital dislocation (adults) From 1943 till 1960 360 hip joints were operated upon in this way In the first part of this period the main procedure was Smith Petersen cup arthroplasty Later on Judet s arthroplasty and different types of intramedullary arthroplasties were used to a certain degree alternating with cup-arthroplasty and arthrodesis and in the last part of this period arthrodesis was the usual operation If an arthroplasty is indicated the type used now is the cup-arthroplasty of Smith Petersen and rather seldom the intramedullary replacement operation and if so the Moore prosthesis is preferred

Osteoarthritis has been the main indication for surgery (Table 1)

The age distribution shows that some young individuals are operated upon too (Table 2) and the indication for operation upon cases under the age of 14 has in most of them been coxitis

TABLE 1
The aetiological diagnosis of 360 arthrodesis and arthroplasties of the hip joint

Osteoarthritis	262
Rheumatoid arthritis	4
Coxitis	11
Post traumatic conditions	31
Congenital dislocation (Adults)	48
Postpoliomyelitic paralytic hip	4
	360

TABLE 2
The age distribution of 360 arthrodesis and arthroplasties of the hip joint

Age at operation	Arthrodesis	Arthroplastie	Sum
Under 10 years	4	2	6
10–14 years	6	6	12
15–19 years	14	10	24
20–29 years	13	28	41
30–39 years	16	29	45
40–49 years	20	48	68
50–59 years	24	56	80
60–69 years	13	57	70
70–79 years	1	13	14
Sum	111	249	360

Table 3 shows the result of all the 360 hips belonging to 297 individuals operated upon The requirements for an excellent result classification have been 1 For arthrodesis Consolidation functional good position full time working ability and no pain 2 For arthroplasty satisfactory mobility with more than 60 degrees flexion full time working ability no pain apart from overexertion and satisfactory stability

Table 4 shows the results for different methods in per cent It is evident that in our hands the result after Smith Petersen cup plasty is better than after the other types of arthroplasty The main observation time after Judet s replacement arthroplasty was over 7 years and after intramedullary replacement arthroplasty 5 5 years

TABLE 3

The results of 360 operated hips (adults) operated upon for osteoarthritis post traumatic conditions and congenital dislocation

Result	Category of operation					Sum
	Arthrodesis	Different types of arthroplasties				
		Smith Petersen cup-plasty	Judet prosthesis	Intramed. prosthesis	Other method	
Excellent	79	40	4	6	2	131
Good	19	53	14	15	4	105
Fair	8	28	8	9	2	55
Poor	3	27	11	14	1	56
Dead	0	0	0	0	0	0
Not followed up or dead later on	2	6	2	3	0	13
Sum	111	154	39	47	9	360

22 cases with bad results after arthroplasty have been reoperated and undergone arthrodesis with excellent or good results

TABLE 4

Percentage comparison between the results of arthrodesis and different types of arthroplasties of the hip joint (For the numbers see Table 1)

Result	Category of operation			
	Arthrodesis	Different types of arthroplasties		
		Smith Petersen cup-plasty	Judet prosthesis	Intramed. prosthesis
Excellent	72.4 %	27.1 %	10.8 %	13.6 %
Good	17.7 %	35.8 %	37.8 %	34.1 %
Fair	7.3	19.8	21.6 %	20.5
Poor	2.6	18.2 %	29.8 %	31.8
	100 %	100 %	100 –	100 – %

Table 4 is a percentage comparison between arthrodesis on the one side and all types of arthroplasties together on the other According to the requirements for classification the result after arthrodesis is far superior The drawbacks of even an excellent anchylotic hip must however be considered The inconvenience in being unable to bend the hip joint the greater vulnerability of the corresponding femur and the long time tendency to instability of the corresponding knee joint

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to heavy work is rather slight but if the patient is young enough he can be rehabilitated to an easier job The treatment of choice in these cases is an arthrodesis on the one side and an arthroplasty on the other

TABLE 6

Working ability after unilateral hip operation for unilateral hip lesions Patients over 70 years of age are not included in this observation

Working ability	Category of operation				Sum	
	Arthrodesis		Arthroplasty			
Full time work	58	84 1 %	65	60 2 %	123	69 5 %
Part time work	8	11 6 %	17	15 7 %	25	14 1 %
Unable to work	3	4 3 %	26	24 1 %	29	16 4 %
Sum	69	100 – %	108	100 %	177	100 – %

Two disadvantages of arthrodesis the long lasting recumbency in a big plaster spica and the tendency to pseudarthrosis are overcome by the new method published in another report in this issue By means of a solid and reliable fixation this method allows the patient out of bed a few days after operation with a short spica and he can walk around and stay at home during the convalescent period

TABLE 7

Working ability after uni r bilateral hip operation f r bilateral hip l sion

Working ability	Category of operation				Sum	
	Arthrodesis		Arthroplasty			
Full time work	28	70 %	47	39 9	75	47 5 %
Part time work	8	20 –	32	27 1	40	25.3 %
Unable to work	4	10 –	39	33 – %	43	27 2 %
Sum	40	100	118	100	158	100 – %

Only 6 out of 158 with bilateral hip lesion had bilateral hip operation 7 work full time 5 work part time and 14 are unable to work

Table 6 shows the working ability after operative treatment of unilateral lesions of the hip joint in adults (osteoarthritis, post-traumatic conditions and old congenital dysplasia).

Table 7 demonstrates the working ability after uni- or bilateral hip operation for bilateral hip lesion. According to our experience an arthroplasty on one side for bilateral hip lesion usually induces greater discomfort in the non-operated side after the operation, but an arthrodesis usually reduces the discomfort in the other side. Because of that the working ability after a unilateral arthrodesis for bilateral hip lesion is much better than after a corresponding arthroplasty.

SUMMARY

From 1943 till 1960 360 hip joints with osteoarthritis, severe post-traumatic conditions and congenital dislocations (adults) were operated upon, the procedure being arthrodesis or some type or other of arthroplasty. Osteoarthritis has been the main indication for surgery. The result after arthrodesis is far superior to arthroplasty.

The working ability of heavy workers is especially better after an arthrodesis than after an arthroplasty. The treatment of choice of severe disabling bilateral hip lesions is arthrodesis on the one side and arthroplasty on the other.

Concerning the arthroplasties in our hands the result after Smith-Petersen cup plasty is better than the result after the other types of arthroplasty. Persistent low back pain after hip arthrodesis is not common *providing the anchylotic hip has a functional good position giving* the spine a good alignment. The functional best position of the anchylotic hip is about 25 degrees flexion and from 2 to 5 degrees adduction and a few degrees external rotation. An osteochondrotic lumbar spine is no contraindication for hip arthrodesis providing a good alignment of the spine follows after the fusion.

RESUME

De 1943 à 1960 360 articulations de la hanche avec osteoarthrite, lésions posttraumatiques graves et dislocations congenitales (adultes) ont été operées selon la procedure de l'arthrodese ou d'une espece d'arthroplastie. L'osteoarthrite a été la principale indication de l'intervention chirurgicale. Le resultat après l'arthrodese est sensiblement supérieur à celui de l'arthroplastie.

La capacité de travail chez ceux ayant à fournir un travail dur en particulier est meilleure après une arthrodèse qu'après une arthroplastie. Le traitement de choix dans les cas de grave incapacité provoquée par des lésions bilatérales de la hanche est l'arthrodèse d'un côté et l'arthroplastie de l'autre.

En ce qui concerne les arthroplasties que nous avons eues entre nos mains, le résultat obtenu par la méthode de Smith Petersen est meilleure que celui obtenu par les autres types d'arthroplastie. Des douleurs lombaires persistantes après l'arthrodèse de la hanche ne sont pas communes, à condition que la hanche ankylosée ait une bonne position fonctionelle donnant un bon alignement à la colonne vertébrale. La meilleure position fonctionelle de la hanche ankylosée est d'environ 25 degrés de flexion, entre 2 et 5 degrés d'adduction et quelques degrés de rotation externe. Une colonne lombaire ostéochondritique n'est pas une contre-indication de l'arthrodèse de la hanche à condition d'un bon alignement de la colonne après la fusion.

ZUSAMMENFASSUNG

Von 1943 bis 1960 wurden 360 Hüftgelenke mit Osteoarthritis, schweren posttraumatischen Zuständen und angeborenen Hüftverrenkungen (Erwachsene) mittels Arthrodesis oder einer Syme Type oder anderen Form von Arthroplastik operiert. Osteoarthritis war die Hauptindikation für den chirurgischen Eingriff. Das Ergebniss nach Arthrodesis ist dem der Arthroplastik weit überlegen.

Die Arbeitsfähigkeit des Schwerarbeiters ist vor allem besser nach einer Arthrodese als nach einer Gelenksplastik. Die Behandlung der Wahl von stark invalidisierender doppelseitiger Hüfterkrankung ist die Arthrodese auf einer Seite und die Arthroplastik auf der anderen.

Hinsichtlich der von uns ausgeführten Arthroplastiken ist zu sagen, dass das Ergebnis nach Smith Petersens Gelenksplastik besser ist als nach anderen Methoden der Athroplastik. Anhaltende Kreuzschmerzen nach Hüftversteifung ist keine gewöhnliche Erscheinung, vorausgesetzt dass die Hüfte in guter funktioneller Stellung versteift ist, so dass die Wirbelsäule gute Anpassungsmöglichkeiten hat. Die beste Funktionsstellung der versteiften Hüfte ist ungefähr 25° Beugung, 2–5° Adduktion und wenige Grade Aussenrotation. Eine osteochondrotische Lendenwirbelsäule ist keine Kontraindikation gegen Hüftarthrodese vorausgesetzt, dass eine gute Anpassung nach der Versteifung zustande kommt.

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FROM THE CHILDREN'S HOSPITAL UNIVERSITY OF HELSINKI FINLAND

CONGENITAL ABSENCE OF THE FIBULA

By

M. SULAMAA and S. RYÖPPY

Next *to absence of the radius* the commonest defect of the long bones of the extremities is congenital absence of the fibula It is one of those malformations which have become very much more frequent during the past years chiefly as the result of the Thalidomide accident (13)

We have earlier discussed the embryological aethiological and pathoanatomical problems connected with defects of the long bones of the extremities in general as well as the general principles of treatment (10) *The present paper presents some experience gained in the treatment* of six cases of congenital absence of the fibula

The classical picture of fibular defect includes complete absence of the fibula a bent tibia which is shorter than normal a dimple in the skin on the anterior surface of the leg talipes equinovalgus position of the foot absence of one or more fibular rays of the foot absence or fusion of one or more tarsal bones and a hypoplastic femur The defect may also be partial bilateral and/or combined with other defects (3 4 5 6 11)

Opinion regarding treatment is divided Conservative measures (manipulation casts) are generally resorted to first The recent trend *seems to be towards surgical intervention* (2 3 4 5 7 8 11) Besides the deformity of the foot the shortness of the extremity constitutes a difficult problem Amputation is often said to be inevitable *Perkins* follows a conservative line carrying out amputation at the final stage of growth *Coventry & Johnson* perform palliative operations (soft tissue correction and osteotomy of the tibia) from the second or third year onwards *Thompson et al* attribute the foot deformity and the bowing of the tibia to the presence of a taut fibrous band replacing the fibula which they believe should be cut in infancy According to them considerable correction of the tibial bowing and the valgus position is achieved in this way *Thompson* (12) is of the opinion that the best



Fig 1 A



Fig 1 B

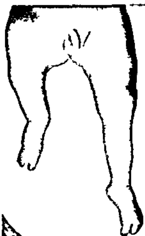


Fig 1 C

Case 1 Figures 1 A B before treatment Fig 1 C at the age of [illegible] years

result is obtained by combining this treatment with Syme's amputation carried out at the completion of growth He stresses the fact that below knee amputation during the growth period often leads to unsatisfactory development of the stump during the course of growth *Aitken* recommends amputation during the early growth period particularly if considerable shortening must be expected *Farmer & Laurin* likewise carry out amputation in severe cases at an early age

CASE REPORTS

Case 1 (5737 58) A S Male Total absence of the right fibula (Figs 1 A–C) He was brought for treatment at the age of 3 months The right lower extremity was shorter than the left the shortening comprising both the thigh and the leg The knee was in pronounced flexion contracture the foot being fixed in the talipes equinovalgus position There was a dimple in the skin on the anterior surface of the leg There were only four toes on each foot The left lower extremity was otherwise normal The radiogram showed a short and bowed right femur The tibia was bent the convexity being anteromedial

At the age of 3 months osteotomy of the tibia was carried out the proximal epiphysis of the left fibula with its epiphyseal cartilage being transferred to the site of the osteotomy In a short time this transplant fused however showing no trace of the expected growth in length At the age of 1½ years osteotomy was repeated and achillotenotomy carried out since the malposition had increased After this operation the position was satisfactory Because of contraction of the knee joint a cuneiform resection of the femur was performed at the age of 3 years At the age of 3½ years the motility of the knee joint is 140 to 110 degrees The motility of the foot



Fig 2 A *Fig 2 B* *Fig 2 C*

Case 2 Fig 2 A before treatment Fig 2 B–C at the age of 4 years

in the ankle joint is almost normal The extremity is 12 cm shorter than the left lower extremity The patient walks well with the aid of an orthopaedic boot

Case 2 (609/59) V K Male Ttotal absence of the right fibula (Figs 2 A–C) He was brought for treatment at the age of 6 months The femurs were of equal length The right tibia was short thick, and convex in the antero medial plane The foot was in moderate valgus and slight equinus position The patient was first treated with redressement and a brace but without result At the age of 2 years and 9 months osteotomy of the tibia and achillotenotomy were carried out with simultaneous excision of the fibular fibrous bands At the age of 4 years and 3 months the right tibia is 9 cm shorter than the left and moderate bowing remains in the tibia The motility in the knee joint is normal The patient walks well with an orthopaedic boot

Case 3 (494/59) J J Male Total absence of the right fibula (Figs 3 A–D) He was brought for treatment at the age of 3½ months The right femur was slightly shorter than the left The tibia was short and convex in the antero medial plane There was moderate flexion contracture in the knee and the foot was in extreme equino valgus position Two fibular toes and metatarsal bones were missing Osteotomy of the tibia was carried out At the same time the third metatarsal bone was transferred to the site of the fibular malleolus Further achillotenotomy and excision of the taut fibular bands were carried out Because of impairment of the position osteotomy and achillotenotomy were repeated 1½ years later The position was then satisfactory Two years after the last operation the tibia is now quite straight but it is barely two thirds the length of the left tibia The position of the foot is comparatively good The boy who is now almost 4 years old walks well with the aid of an orthopaedic boot

Case 4 (4677/59) S H Female Total absence of the left fibula (Figs 4 A C) She was brought for treatment at the age of 4 days The right lower extremity was entirely missing The upper end of the left femur was dysplastic and in pronounced








Fig 3 A *Fig 3 B* *Fig 3 C* *Fig 3 D*

Case 3 Fig 3 A B before treatment Fig 3 C D at the age of 2 years






Fig 4 A *Fig 4 B* *Fig 4 C*

Case 4 Fig 4 A before treatment Fig 4 B C at the age of 3 years

c xa ara positi n The tibia was convex in the antero medial plane and the foot wa in marke l equino-valgus positi n Three fibular metatarsal bones and toes were mis ing

At the age of 2 weeks oste tom of the tibia achilloten tom and excision of taut fibular bands were carried out Follow up at the age of 3 years and 3 months showed go d functi n of the hip and knee The tibia is straight The foot is in slight equino-lgu p iti n Since the function of the left lower extremity i good the patient will probabl be able t walk with the aid of a pr sthesis

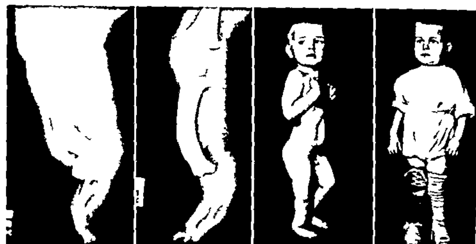


Fig. 5 A *Fig. 5 B* *Fig. 5 C* *Fig. 5 D*

Case 5. Fig. 5 A. before treatment. Fig. 5 B–D. at the age of 3 years.

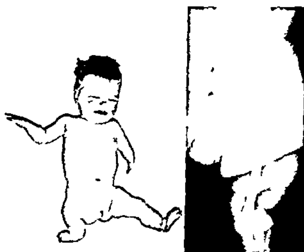


Fig. 6 A *Fig. 6 B*

Case 6. Fig. 6 A–B. before treatment.

Case 5. (5587/60) J. M. Male. Total absence of the right fibula. He was brought for treatment at the age of 10 months. The right femur was normal. The tibia was short and curved. The foot was in moderate valgus position. The left foot lacked the fifth toe and a metatarsal bone.

Osteotomy of the tibia was carried out at the age of 10 months. Two months later the operation was repeated, the position being corrected. Achillotenotomy and excision of a fibrous fibular band were also made. At the age of 3 years there is still moderate bowing of the tibia. The foot is of a slightly rocking chair shape with

the calcaneus turned in the proximal direction The patient walks very well with the aid of an orthopaedic boot

Case 6 (1179 62) R N Female Total absence of the right fibula

She was brought for treatment at the age of ¾ year The right knee was almost at the level of the hip in rather pronounced flexion contracture with the foot in marked valgus position Otherwise the foot was almost normal The radiograph showed only the distal part of the femur The tibia was straight In addition the patient had a subtotal radius defect on the left side and hypoplasia of the right radius There were two fingers only on either hand Since treatment was primarily directed at the femoral defect treatment of the fibula has so far been conservative

Clinical Picture

All the cases described above are unilateral total defects of the fibula 4 of the patients were boys and 2 girls With one exception all defects were right sided In all but one of our cases the tibia was thicker and shorter than normal and bowed with antero medial convexity At the the site of the tibial curvature there was a dimple in the skin on the anterior surface of the leg The foot was in most cases in more or less marked equino valgus position The Achilles tendon the fibular tendons and the fibrous bands were taut and prevented redressement of the ankle joint In the fibular portion of the leg and foot there were often defects of the muscles and other soft tissues as well In some cases the talus seemed to be missing either entirely or partly The fibular meta tarsal bones and toes were mostly absent The knee was often in flexion contracture which however was slighter and was less resistant than the contracture of the ankle The femur was normal in only two out of the six cases In two cases it was shorter than normal in one there was marked coxa vara and in one case there was a subtotal defect of the femur

Treatment

In one case in which the fibular defect was combined with subtotal defect of the femur in the same extremity the treatment has so far been conservative In the remaining five cases operation as shown in Fig 7 has been carried out The tibial surface was exposed subperio steally through a longitudinal incision and a cuneiform osteotomy of the tibia performed Achillotenotomy was further carried out in all cases and in four cases the taut bands were severed at the site of the missing malleolus We did not aim at complete correction of the equinus position The tibia was fixed in position with a Kirschner nail intro duced from under the foot into the tibia Immobilization was achieved

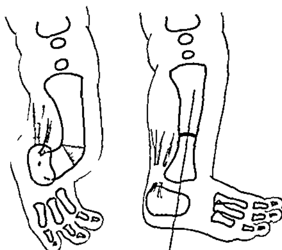


Fig 7

with a plaster cast extending from the base of the thigh to the toes The nail was removed two weeks after the operation The tibial fusion was normal in all cases In a couple of cases satisfactory correction was only obtained after reoperation

RESULTS OF TREATMENT

The age of the patients at the time of the operation ranged from 2 weeks to 2 years and 9 months The postoperative period of observation varies between 1½ years and 3 years and 3 months This period of observation is too short to allow conclusions as to the final results of treatment but during this period the tibial angulation and the position of the foot have not changed Four of the five patients treated operatively are able to walk well with the aid of an orthopaedic boot In the fifth patient (Case 4) it is the fact that one extremity is entirely missing that prevents her from walking From the point of view of function the knee joint was good in all cases The tibia is either quite straight or there remains a slight anterior bowing

There is often a rocking chair like deformity in the foot The shortness of the tibia necessitates the use of an orthopaedic boot which compensates the shortening of the affected leg

DISCUSSION

In addition to the severity of the defect the result of the treatment largely depends on how early operative measures can be undertaken

The fibular defect is probably the result of a disturbance at the stage of the formation of the fibular anlage in the fifth week of pregnancy The experiences gained in the Thalidomid cases in particular indicate the truth of this assumption (10 13) Heredity has also been established (6) The disturbance is not confined to the skeletal parts alone but other tissues in the same area are also affected The deformation in the extremity does not automatically become corrected during the course of growth as often happens for instance in a sound extremity in children with fractures healed in a poor position During the period of the foetal development a severe deformity may often have developed from secondary causes

By conservative measures redressement and bandages satisfactory results may possibly be achieved in mild cases seen at an early age If the tibia is badly curved however and if there is a taut fibrous band at the site of the fibula the value of conservative treatment is doubtful

It is our opinion that osteotomy of the tibia in conjunction with tenotomies and excision of the fibular bands is the best method of treatment The operation should preferably be carried out in early infancy With the method adopted by us a comparatively straight tibia and satisfactory correction of the valgus position have been achieved The marked shortness of the leg constitutes the most difficult problem It makes the use of an orthopaedic boot inevitable The degree of the final shortening of the leg and the necessity of amputation at a later stage cannot yet be evaluated in these cases In our opinion amputation during childhood is not to be recommended

SUMMARY

On the basis of a series of 6 cases of total congenital absence of the fibula the clinical picture and treatment of this deformity is discussed The authors stress the importance of early operative treatment Surgical correction comprising a cuneiform osteotomy of the tibia achillotenotomy and when necessary excision of taut fibrous fibular bands was carried out By this procedure it was possible to achieve satisfactory straightening of the tibia and correction of the valgus position in the majority of cases The patients were then able to walk with the aid of an orthopaedic boot The authors do not recommend amputation during childhood

RÉSUMÉ

Basés sur l'étude d'une série comprenant 6 cas d'absence totale congénitale du péroné, le cadre clinique et le traitement de cette anomalie sont discutés. Les auteurs soulignent l'importance d'un traitement précoce. La correction chirurgicale comprend l'ostéotomie (résection en coin) du tibia, l'achillotenotomie et, lorsqu'elles sont présentes, l'excision des bandes fibreuses péronéales. En utilisant cette technique il a été possible d'obtenir dans la majorité des cas un redressement satisfaisant du tibia et de corriger la position en valgus. Les malades ont été capables de marcher avec l'aide d'une botte orthopédique. Les auteurs ne sont pas partisans de l'amputation pendant l'enfance.

ZUSAMMENFASSUNG

Das klinische Bild und die Behandlung von sechs Fällen totales kongenitales Defekt der Fibula wird diskutiert. Die Wichtigkeit der frühzeitigen operativen Behandlung wird betont. Keilosteotomie der Tibia, Achillotenotomie und Resektion der fibrösen Strängen wurden ausgeführt. In meisten Fällen ist es möglich gewesen eine genügende Verbesserung der Deformität zu erreichen. Die Patienten konnten mit Hilfe einer orthopädischen Schuhe gehen. Die Amputation im Kindesalter ist nicht zu empfehlen.

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FROM THE ORTHOPAEDIC DEPARTMENT UNIVERSITY OF UPPSALA SWEDEN
FORMER CHIEF ACTING PROF J A SEVASTIKOGLOU M.D

INSULIN INDUCED MICROMELIA IN CHICKENS

I Morphological Study

By

JOHN A SEVASTIKOGLOU M D

Since the early days of medicine congenital malformations have always attracted attention Interest in the study of these conditions has however grown progressively since the beginning of the 20th century when statistical reports on the occurence of congenital abnormalities and the correlation between their frequency and various pathological affections of the mother organism during gestation demonstrated an unbelievably high frequency of these conditions Furthermore the development of the new methods of investigation during the last decades has greatly increased the possibilities of studying the problem from different aspects

Experimental teratogenesis is one of the methods of biological investigation more frequently used for the study of congenital malformations The application of this method for more than one century has added a great deal to our knowledge regarding the morphological development and the influence of different environmental factors on the production of these abnormal conditions Mechanical X ray anoxic chemical and other factors applied to pregnant animals or fertilized hens eggs have been proved to give a teratogenetic response

In a large series of experiments *Landauer* (1945) found that insulin injected into the yolk sac of fertilized hens eggs before or during the early stages of incubation had a teratogenetic effect inducing rumplessness Injection at later stages of incubation was responsible for deformities of the beak the extremities and the eyes (*Landauer* 1947) During the following years Landauer and his co-workers published several works on the teratogenetic properties of insulin Several other investigators (*Duraiswami* 1952 *Zwilling* 1952 *Anderson et al* 1959 and others) later confirmed the observations made by Landauer Other

substances were also proved to induce similar developmental malformations when injected into eggs. An extensive list of references to the early investigations can be found in the work of *Duraiswami* (1952).

The experience gained by these and numerous other works on experimental teratogenesis can be summarized by the statement recently made by *Hamilton* (1960) that a) there is a multiplicity of agents that can produce abnormalities, b) the time factor when the particular agent is administered is of importance and c) that early embryonic tissue is susceptible to particular noxious agents.

The present investigation has been undertaken to study and compare the biochemical composition of the skeleton during the embryonic development of normal and insulin induced micromelic chicks. Morphological and histological studies of the material have also been performed. The purpose of this work is to look for correlation between the morphological—histological changes and the biochemical composition of the skeleton during normal and teratogenic embryonic development. In this paper the morphological observations are described and discussed.

MATERIALS AND METHODS

Insulin was injected into 1094 eggs, a physiological saline solution into 40, while 741 untreated fertilized eggs were incubated and served as controls.

The injection technique used was as follows: the egg shell was carefully washed first with an antiseptic solution, then with alcohol and it was opened on the air chamber with sterile forceps. Using good illumination the embryo and the vessels of the vascular area were easily seen. Using a tuberculin syringe a very fine hypodermic needle was driven through the inner layer of the shell membrane into the yolk sac avoiding any injury of the embryo and the vessels. The insulin or saline solution was then injected very slowly. The needle was carefully withdrawn and the egg was coated with a sheet of sterile aluminium foil and placed in the incubator at 37° C. The temperature was never found to exceed the range of ± 0.5° C.

Crystalline insulin insulin was employed.[1] On the day of injection an insulin solution in physiological saline was prepared in concentration of 5 mg or 120 I.U./ml. Since crystalline insulin is insoluble at room

[1] The insulin used was kindly delivered by the Pharmaceutical Co. Vitrum, Stockholm, as 7 times crystallized pure powder substance.

temperature at neutral pH the solution was acidified by adding 3–4 drops in 1n HCl per 10 ml volume In this way a clear solution was obtained with a pH between 3 9 and 4 1 In a control series of 234 eggs insulin solution was made in a phosphate buffer with pH of 7 4 Before use the solutions were passed through a sterile glass filter (G5)

The dose of insulin injected in all the cases was 6 1 U i e 0 25 mg crystalline insulin or 0 05 ml of the solution per egg

All eggs were injected 96 hours after incubation and material was collected by opening a certain number of eggs at 24 hours interval up to the time of hatching Embryos found dead at opening were discarded

From the material collected every day both tibiae were dissected free from soft tissue and were stored either by deep freezing at —15 C for biochemical analysis or in a 10 per cent neutral formaldehyde solution for histological sectioning

Morphological studies of the occurrence of micromelia were based mainly on measurements of the length of the freshly prepared tibiae and by weighing each bone after thawing before the performance of the chemical analysis As the purpose of the present investigation was to study insulin induced micromelia no systematic record of other deformities in the embryos were made

Histological studies were based on serial sections of the specimens in 3 μ thick slices using haematoxylin eosin toluidine blue and Azan stainings

RESULTS

Of the total of 1094 eggs injected with insulin 215 embryos survived the injection The average mortality rate in the various insulin injected series was 80 3 ±1 2 per cent In the 40 saline injected eggs the mortality was 70 0 ±7 3 per cent The mortality rate between eggs injected with acid and neutral insulin solution was 77 4 ±1 5 and 91 0 ±1 9 per cent respectively the difference being highly significant Among the 741 fertilized eggs used as controls the mortality observed was 18 4 ±1 5 per cent

Morphological studies Macropscopical observations on general deformities present both in normal and treated specimens were possible only after the 7th or 8th day of incubation Until this stage of development the embryos are very small and transparent so that any anomalies in

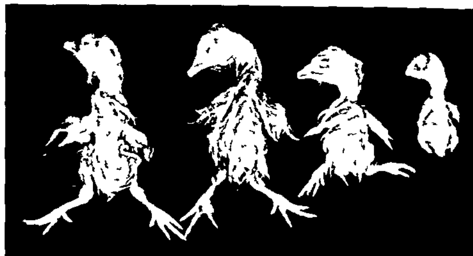


Fig 1

17 day old chicken embryos From the left a) normal b) injected with physiological saline c) insulin injected with marked micromelia but without other apparent abnormalities and d) insulin injected with extreme micromelia and multiple abnormalities of the chondrodystrophic type

their development are difficult to observe After this period of incubation anomalies such as anencephaly anophthalmos ectopic viscera club feet etc can easily be distinguished Such deformities were often observed in the insulin injected material No deformity was observed in the 12 surviving animals injected with physiological saline and opened the 17th day after incubation As mentioned earlier no records were made of the frequency of such anomalies Malformed embryos present among the normal material were discarded Deformed embryos were included in the injected material

Compared to the normal controls the insulin injected embryos displayed two different types of abnormality In the majority of the cases the embryos were appreciably smaller than normal but as far as it was possible to ascertain they were of the same stage of development and showed no generalized abnormalities The second type of abnormal development was found in certain embryos which had a monstrous appearance with a very small size distorted extremities head and beak deformity joint stiffness reminding arthrogryphosis and oedematous soft tissues (Fig 1) The dissection of the tibiae in this group of deformed embryos was especially difficult as the bones were soft and fragile and the soft tissues were tightly attached to the bones

The occurrence of micromelia in general was obvious in every case of insulin injected embryos The tibial length was found to be less than the average of the values for normal bones of the same age of incubation in every case after the 8th day of incubation The ratio of micromelia to highly deformed embryos was 2 1 as was found from the study of 91 insulin injected tibiae

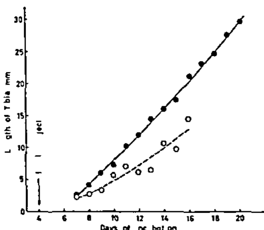


Fig 2

The course of the average tibial length during the embryonic development in normal (continuous line) and insulin treated (broken line) material The dotted line is based on the statistical extrapolation of the values obtained in the insulin treated material in comparison to the normal

The tibial length was recorded between the 7th day of incubation and hatching in the normal material and between the 7th and 16th days of incubation in the insulin injected embryos The curve of tibial length of insulin injected embryos compared to that of normal material showed that after the 8th and up to the 16th day of incubation there was an obvious divergence in the two curves the insulin treated tibiae being clearly shorter than the normal A rightly statistically significant difference between the average tibial length in normal and insulin treated material appeared first the 8th day of incubation The insulin treated material was insufficient for observations to be made after the 16th day of incubation The statistical extrapolation of the curve however showed that increasing divergence of the curves continued up to the time of hatching The course of both curves during the period of incubation followed a regular linear rise (Fig 2)

The wet weight of the tibia was studied between the 8th and 20th days of incubation in the normal and between the 8th and 17th days of incubation in insulin treated material The tibial weight of insulin injected embryos showed no statistical difference from the normal between the 8th and 10th days of incubation Statistically significant differences were however obtained from the 11th day of incubation and thereafter the difference increasing progressively up to the 17th day of incubation Statistical extrapolation showed that increasing divergence of the curves continued until the hatching The course of the mean tibial weight values in insulin treated and normal material followed in both the cases regular parabolic curves (Fig 3)

Histological study The observations reported here are based on sectioned material from a) 4 tibiae obtained from control untreated embryos at the 15th and 17th days of incubation respectively b) 4 tibiae from embryos at the 17th day of incubation injected with physiological saline c) 2 tibiae at the 9th day of incubation from insulin injected embryos d) 4 tibiae at the 17th day of incubation from insulin injected micromelic embryos without other anomalies and e) 4 tibiae from insulin injected embryos with generalized skeletal deformities as mentioned above from the 15th and the 17th days of incubation respectively

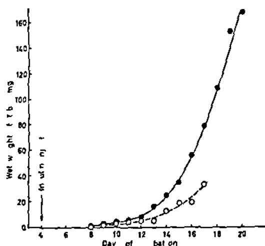


Fig 3

The course of the average tibial wet weight during the embryonic development in normal (continuous line) and insulin treated (broken line) material The dotted line is based on the statistical extrapolation of the values obtained in the insulin treated material in comparison to the normal

The periosteal ossification of the tibia in the normal chick begins at about the 9th day of incubation. A thin bony ring appears first at the middle of the diaphysis while the remainder of the diaphysis as well as both epiphyses are composed of cartilage disposed in characteristic layers. After this the ring elongates at the epiphyses and the characteristic bony cylinder of the long bones develops in this way.

The 9 day old tibiae of insulin injected embryos were almost exclusively composed of cartilage and they did not show any deformity or abnormality. In some places at the middle of the shaft signs of primitive bone trabeculae could be identified by Azan staining. The insulin injected tibiae had much the same structure as normal tibiae at the same stage of development. The metachromatic staining of the cartilage was in the insulin treated tibiae less pronounced than in the controls. In both cases it was however uniform through all the extent of the sections.

The 17 day old tibiae from physiologic saline injected embryos and the 17th day tibiae from insulin injected embryos which did not show skeletal abnormalities other than micromelia showed no significant differences in morphology, metachromatic staining and the grade of development from normal bones of the same age.

The 15 and 17 day old tibiae of the insulin injected embryos which except for an extreme dwarfism showed generalized skeletal deformities too showed several structural differences compared to the normal bones of 15 and 17 days of incubation. The zone of flattened chondrocytes of the epiphyseal cartilage cone corresponding to the resting cell cartilage of the mammals was narrower and in some epiphyses almost missing, while the structure of the rest of the cartilage cone was irregular. The hypertrophied cartilage cells were somewhat more numerous and showed a slight increase in their metachromatic staining. The periosteal bone of the diaphysis was significantly less than normal and the bony trabeculae were thinner and more irregular. The diaphyseal bony cylinder was appreciately shorter while the height of the cones was almost the same as in the normal tibiae. The bone as a whole was thicker and the epiphyses were larger than in the normal. A striking difference between the insulin injected tibiae of this group and normal bones was that the former showed a strong bending of the bone localized in the lower third of the diaphysis. The bending present in all the examined tibiae exceeded in several cases the 90° angle. The diaphyseal bony trabeculae showed a special arrangement at the site of the bending. There were no signs of fresh or healed fracture at the site of an

gulation. A marked thickening of the periosteum was present at the concavity of the angulation. In this group of specimens the metachromatic staining of the insulin treated material was much less pronounced than the specimens of the control group.

DISCUSSION

The total mortality rate among the insulin injected embryos in the present material was 80.3 ± 1.2 per cent and this was considerably higher than in other reports. In *Landauer's* (1947) series mortality rates of 25.7 and 48.8 per cent were reported after injection of 2 or 5 I.U. insulin respectively at the 96th hour of incubation. *Anderson and co-workers* (1959) found in their series a mortality rate of 31.1 per cent by injection of 3–6 I.U. insulin between the 72nd and the 120th hours of incubation. The high mortality rate in the present material was first attributed to the acid pH of the injected solution. However, as already pointed out above, in comparative experiments using acid and neutral insulin solutions the mortality rate was found significantly higher in eggs injected by the neutral solution. The applied technique of injection might to some extent be responsible for the high mortality since other authors use a somewhat different technique of injection. It can also be assumed that the seasonal quality of the eggs, which has been proved to influence the mortality rate of the embryos as well as the appearance of spontaneous occurring deformities (*Hutt & Greenwood* 1928) was a contributing factor to the observed mortality.

Considering the averages of the tibial length, micromelia in insulin treated material occurred in every case after the 8th day of incubation. *Landauer* (1947) found single micromelia at a maximum of 87.3 per cent when 5 I.U. insulin were injected at 120 hours of incubation. This frequency was decreased if insulin was injected at earlier or later stages of embryonic development. *Anderson and co-workers* (1959) found on the other hand a frequency of generalized dwarfism in 31 per cent among the injected material of their investigation. The ratio of micromelia to highly deformed embryos was in the present material 2:1.

The existence of a congenital abnormality in the chicken resembling the condition known in mammals as "chondrodystrophia foetalis" has been reported first by *Landauer & Dunn* in 1925 and later by *Hutt* (1928) and *Hutt & Greenwood* (1928). *Landauer* in 1947 was able to induce such developmental abnormalities in chickens by injecting insulin in the yolk sac at about the 4th day of incubation. The morpho-

logical and histological appearances of the spontaneously occurring and the insulin induced anomalies were strikingly similar. These results of *Landauer* have been confirmed later by *Zwilling* (1952). Both these authors found in their material a variation of the degree of the induced micromelia ranging from a slight shortening of the extremities to advanced and multiple skeletal deformities which could be classified as chondrodystrophia.

The results reported in the present communication are on the whole in agreement with those reported by *Landauer* and *Zwilling*. The findings however showed that there were two distinctly different skeletal abnormalities induced by the insulin injection, i.e. 1) a mere shortening of the legs of the insulin injected embryos without other apparent morphological or histological divergences from the normal bone and 2) an extreme shortening of the legs with important histological changes of the bone combined with other generalized malformations and manifest skeletal deformities. Skeletal deformities of both types appeared in every case in the insulin treated material. However statistical evidence provided from the estimations of the length and wet weight of the tibia from control and insulin injected material show that micromelia appears first between the 8th and 11th days of incubation, i.e. 4 to 7 days after the injection of insulin in the eggs. In the light of these observations, not mentioned by earlier authors, it might be assumed that insulin interacts in some of the early stages of bone formation. It is known (*Fell* 1925) that periosteal bone is laid down in the cartilagenous extremities at about the 9th day of incubation. The effect of insulin on osteogenesis might result in an irreversible distortion of the course of the process, followed by the development of the skeletal deformities described.

SUMMARY

Injection of 6 I.U. insulin in hen's eggs at the 4th day of incubation induces skeletal abnormalities of two main types, i.e. single micromelia without other manifest malformations and extreme dwarfism combined with other generalized and skeletal deformities of the chondrodystrophic type.

Estimations of the length and the wet weight of the tibia in control and insulin injected material provided statistical evidence that the effect of insulin develops first between the 8th and 11th days of incubation, i.e. 4 to 7 days after the injection.

RESUME

L injection de 6 u i d insuline dans des oeufs de poules le 4eme jour de l incubation provoque des anomalies squelettiques de deux types principaux, a savoir micromelie simple sans malformations manifestes et nanisme extreme combine a d autres deformites generalisees et squelettiques du type chondrodystrophique

Les evaluations faites concernant la longueur et le poids humide du tibia dans le materiel de controle et le materiel d observation auquel il a ete administre de l insuline ont fourni la preuve statistique que l effet de l insuline ne se developpe qu entre le 8eme et le 11eme jour de l incubation c est a dire entre 4 et 7 jours apres l injection

ZUSAMMENFASSUNG

Injektion von 6 I U Insulin in ein Huhnerei am 4ten Tage der Ausbrutung verursacht Skelettabnormitaten von zweierlei Haupttypen i e einfache Mikromelie ohne andere manifeste Missbildungen und extremen Zwergwuchs kombiniert mit anderen generalisierten und Skelettmissbildungen der chondrodystrophischen Art

Schatzungen der Lange und des Nassgewichtes der Tibia von Kontrol und insulininjiziertem Material ergab statistischen Beweis dafur dass die Insulinwirkung erst zwischen dem 8 und 11 Brutungstag also 4 bis 7 Tage nach der Injektion auftritt

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FORMER CHIEF ACTING PROF J A SEVASTIKOGLOU M D

INSULIN INDUCED MICROMELIA IN CHICKENS

II *Biochemical Study*

By

J A SEVASTIKOGLOU M D

The mechanism by which the different teratogenic agents induce congenital malformations is largely unknown In the case of insulin induced generalized skeletal deformities in chickens very little is known as to whether there is any response of the teratogenic influence on the biochemical pattern of the skeleton However it may be assumed that the course of the abnormal embryonic development is to some extent reflected in the chemical composition of the bone Furthermore a correlation might exist between the morphological histological and biochemical development of the skeleton If such internal relationship can be proved a better understanding of the mechanism by which the congenital malformations are induced can be expected

Works concerning the biochemical composition of the normal skeleton of the chicken during the embryonic development are very few Similarly biochemical studies of the skeleton during the embryonic development of insulin induced micromelia are extremely rare

Determination of certain chemical components of the embryonic chicken tibia has been performed partly in normal partly in insulin induced micromelic embryos and the results are reported in this paper Furthermore the results obtained here are compared and discussed in relation to the morphological and histological observations made on the same material which have been reported in an earlier publication (*Sevastikoglou*, 1963 a)

The material and the methods used for the collection of normal and insulin induced micromelic bone are the same as in the previous publication The biochemical studies reported here are based on quantitative determinations of the alkaline and acid phosphates activities and the hydroxyproline content of the whole tibiae For determination of the

alkaline and acid phosphatase activities the methods of *King & Armstrong* (1934) as modified by *Sevastikoglou* (1958) was used. Hydroxyproline determinations were performed by the method described by *Newman & Logan* (1950).

RESULTS

The alkaline phosphatase activity of the normal bone was very low and constant between the 5th and 7th days of incubation. It rose between the 7th and 9th days and thereafter almost constant values were obtained up to the 12th of incubation. After this time a very steep rise was observed up to the 16th day and this was followed by a fall at the 17th and 18th days of incubation. The alkaline phosphatase activity in

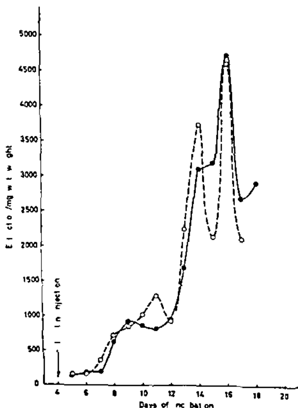


Fig. 1

The alkaline phosphatase activity of the tibia in normal (continuous line) and insulin injected (broken line) embryos during the embryonic development.

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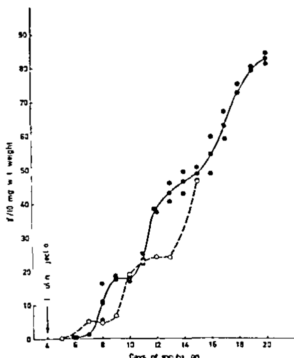


Fig 3

The hydroxyprolin content of the tibia in normal (continuous line) and insulin injected (broken line) embryo during the embryonic development.

DISCUSSION

The nature of the investigation and the difficulty in obtaining sufficient values made it impossible to analyse the results reported in this part of the work statistically. The study of the alkaline and acid phosphatase activity and the collagen content of the tibiae of normal and insulin injected material during the embryonic development provide however evidence that there are differences in the biochemical reactions of the bone in these two groups of material. In their work *Anderson and co workers* (1959) reported that there were no marked changes in the chemical composition of the cartilage cell or its matrix in insulin dwarfism. The results of these authors are however based on estimations of certain substances (glycogen, alkaline phosphatase and phosphorylase activity and chondroitin sulphate) on only the cartilaginous parts of the long bones of the lower extremities of normal and insulin treated embryos 14 days after the injection of insulin into the egg, i.e.

at the 18th day of incubation. Moreover, their results are almost exclusively based on histochemical methods, the value of which for quantitative estimation is questionable.

The evolution of the alkaline phosphatase activity of the normal tibiae during the embryonic development showed a great similarity to the evolution of the enzymatic activity in the cartilaginous cones of normal embryos as previously observed (*Sevastikoglou* 1958). The enzymatic activity increased, however, in the case of the tibiae earlier than in the cones and it showed a decrease at the later stages of embryonic life. The role of this enzyme on the normal osteogenesis is not yet known completely and it has been suggested that alkaline phosphatase is engaged in cell differentiation in general and in the differentiation of the osteoblasts especially in the case of osteogenesis (*Kabat & Furth* 1941, *Moog* 1943 and 44, *Sevastikoglou* 1958 and others). The divergences in the alkaline phosphatase activity observed between normal and insulin treated tibiae in this work appeared first after the 10th day of incubation. During the normal embryonic development of the chick, osteoblasts differentiate from the periosteum of the long bones and lay down bone at about the same time of incubation. The results obtained here provide more evidence for the participation of this enzyme in the process of osteoblast differentiation. Furthermore they provide more evidence for the suggestion made earlier (*Sevastikoglou* 1963 a) that insulin affects the process of osteogenesis itself which starts at about the 9th day of incubation.

Acid phosphatase has only previously on very few occasions been studied in connection with osteogenesis (*Castella*, 1952, *Tonna* 1957, *Sevastikoglou* 1958). The role played by this enzyme in this process is quite unknown. It has been suggested earlier that a relation might exist between acid phosphatase activity and bone matrix formation (*Sevastikoglou* 1958). As in the case of alkaline phosphatase, study of the acid phosphatase activity in the present work showed deviations between normal and insulin treated bone first after about the 10th day of incubation providing more evidence of the role of insulin in the induction of the skeletal deformities.

A point which has been the object of special study was the question of whether there was any difference in the alkaline and acid phosphatase activity between the two types of insulin induced skeletal deformities described earlier (*Sevastikoglou* 1963 a). Special estimations of the enzymatic activities in micromelic tibiae without other manifest deformities and in chondrodystrophic tibiae at the 15th day of incuba-

tion showed no significant differences in the alkaline phosphatase activity However acid phosphatase activity was higher in the chondrodystrophic than in the micromelic bone Because of the unknown role played by the acid phosphatase it is impossible to comment on the value of this observation

The hydroxyproline content of the tibiae indicated their collagen content Hydroxyproline determinations of normal and insulin treated tibiae showed that there was a difference in the values obtained among the bones of the two groups especially marked between 7th and 9th and between 12th and 13th days of incubation These differences might indicate that the collagen content of the insulin treated bones showed a decrease already before micromelia had appeared and after a normalisation of the values at the 9th day a new decline appeared between the 10th and 13th days of incubation The former deviation from the normal is difficult to interpret The latter however might depend on the insulin effect of osteogenesis mentioned previously

The results of this part of the work indciate that there is a connection between the morphological changes described earlier (*Sevastikoglou* 1963 a) and the biochemical response of the skeleton under the teratogenetic influence of insulin Moreover evidence has been accumulated both from morphological and biochemical studies that the abnormal reaction of the skeleton appears first long after the injection of insulin and when the osteogenetic process itself has begun to develop i e the 9th day of incubation of thereabout

The way in which insulin induces congenital abnormalities in the hen embryo has been the subject of several investigations and extensive discussion It is more likely that this hormone produces alteration in metabolism of the embryo and that different tissues have a specific susceptibility towards the noxious influence of insulin during a certain particularly critical period of their development during embryonic life Several experimental works have shown that insulin influences the normal development of the chick by upsetting the carbohydrate metabolism of the embryo *Hanan* (1925) *Dalton & Han al* (1940) *Zwilling* 1948 and *Duraiswami* (1952) by estimations of the blood sugar in treated embryos found that hypoglycaemia occurs after injection of insulin during the early stages of embryonic development Lowered blood sugar values persist until the 12th day of embryonic life and the embryos regain normal blood sugar levels by the 14th day of incubation (*Zwilling* 1948) *Zwilling* also observed that embryos with a marked hypoglycaemia up to the 12th day of incubation showed the most ex

treme skeletal deformities If sugar levels returned to normal between the 8th and 10th days the embryos developed only moderate micromelia The embryos which showed recovery of the normal blood sugar levels by the 8th day of incubation exhibited no deformity at all and were indistinguishable from normal embryos In an attempt to mitigate insulin micromelia by adding glucose *Zwilling* (1952) found that glucose seemed to exaggerate the effect of insulin *Landauer* (1946) and *Zwilling* (1949) found that the morphological affect of insulin could be prevented by simultaneous administration of nicotinamide According to *Zwilling* (1952) these data show that disturbances of the carbohydrate cycle at some point are involved in the production of the anomalies by insulin The author states further (1948) that apparently some mechanism of sugar control which becomes effective some time between the 12th and 14th days of incubation overcomes the hypoglycaemic effects of insulin This statement according to *Duraiswami* (1952) may be supported by the observations of earlier investigators (*Idzumi* 1924 and *Portrin & Aron* 1927) that the embryonic liver of the chick begins to store glycogen in appreciable quantities about the 11th day of incubation and that it is only later that the carbohydrate metabolism in the chick embryo is controlled by interaction between the appropriate endocrine glands which also begin to secrete active hormones at about the same time Based on these observations *Duraiswami* (1952) concluded that presumably insulin could induce the various abnormalities before this control is established in the embryo

Chen (1954) in a study of the insulin effect on chick embryonic 6–7 day old bones grown in tissue culture observed structural changes of the bone explants very similar to these observed in vivo under the influence of the hormone and concluded that its action is a very complex one He further stated that it seems unlikely that insulin affects the production of a single substance such as chondroitin sulphate as suggested by *Duraiswami*

Any discussion of the mechanism by which insulin affects the development of the embryonic skeleton lies beyond the scope of the present investigation In the light of the results obtained in the present investigation it is however evident that insulin injection in fertilized hens eggs induces abnormal morphological and biochemical reactions of the skeleton resulting in deformities which first appear at about the 9th day of incubation At this period of embryonic development bone is laid down in the cartilaginous extremities It can therefore be assumed that insulin by some unknown mechanism intervenes directly

in the process of osteogenesis as for instance by upsetting protein metabolism as it has been suggested by *Young* (1953) More evidence is required before this hypothesis can be accepted

SUMMARY

Apart from the morphological changes described in a previous publiaction insulin injection in fertilized hens eggs at the 4th day of incubation results in abnormal biochemical reactions of the skeleton

A correlation between the morphological and biochemical distortions of the skeleton is apparent appearing first at about the 9th day of incubation

RESUME

A part certaines alterations morphologiques decrites dans une publication anterieure l injection d insuline dans les oeufs de poules fertilisés le 4eme jour de l incubation donne des reactions biochimiques anormales du squelette

La correlation entre ces alterations morpholiques et biochimiques du squelette est evidente n apparaissant que le 9eme jour de l incubation

ZUSAMMENFASSUNG

Abgesehen von den morphologischen Veränderungen die in einer vorhergehenden Veroffentlichung beschrieben wurden verursacht die Insulininjektion in befruchtete Hühnereier am 4 Tage der Ausbrütung auch abnorme biochemische Reaktionen des Skelettes

Eine Wechselwirkung zwischen den morphologischen und biochemischen Veranderungen des Skelettes die erst ungefahr am 9 Tag der Bebrutung auftreten ist offenbar

The important technical assistance of Mrs Lundblad Maunsbach is gratefully acknowledged The investigation was supported financially by the Swedish Medical Council

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FROM THE ORTHOPAEDIC OUT PATIENT CLINIC (HEAD POLL LUTKEN M D) AALBORG DENMARK

OLISTHETIC SCOLIOSIS

By

HENNING TOJNER

Our knowledge of scoliosis is in many respects deficient Very often a case has to be classified aetiologically as genuine or idiopathic In our Clinic we found in the course of two weeks three cases of lumbar torsion scoliosis which we would primarily have been inclined to classify as idiopathic while radiographs of the lumbar spine in the oblique projection showed lumbar spondylolysis We then decided to analyse our material to ascertain the frequency of torsion and scoliosis in patients with spondylolysis and spondylolisthesis

Perusal of the literature soon revealed that the concept olisthetic scoliosis is known and previously described but fairly unheeded in Scandinavian literature

As early as 1888 *Neugebauer* observed typical torsion scoliosis of the lumbar spine which he related to unilateral spondylolisthesis which he called hemiospondylie According to *Taillard* (9) similar cases have later been published by others (4) but the mechanism of this scoliosis was not described in detail until 1937 by *Glorieux & Roederer* (6) (cf Fig 1) Their figure was accompanied by the following explanation

When one spondylolysis—in a spine having bilateral spondylolysis—"gapes the anterior vertebral segment slips over the sacral bone rotating at the same time on the narrower spondylolysis This slipping has several consequences

1 The rotation of the vertebral body gives rise to a lateral shift of the body as the axis of rotation is eccentric The body leaves the mid line approaching the sacro iliac joint closer to the axis of rotation

2 This rotation exerts a traction on the intervertebral disc especially on the side opposite to the axis of rotation This traction reduces the height of the disc In consequence the vertebral body will "sink on the side opposite to the point of rotation

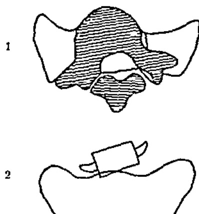


Fig 1
The mechanism of the development of the olisthetic scoliosis in the lumbosacral region (From *Glorieux P* & *Roederer C* La Spondylolyse et ses consequences Masson Paris 1937)

This explanation has been accepted in all essentials by subsequent workers *Taillard* (9) has summed up the criteria of an olisthetic scoliosis as follows

Curvature of the lumbar spine with marked torsion visible particularly on the overlying body The olisthetic body is frequently asymmetrical showing a reduced height on one side Moreover it is exposed to marked torsion but the vertebral arch is not involved in this rotation remaining symmetrical in the anteroposterior view

This is of course the logical consequence of the mechanism in *Glorieux* s sketch *Taillard* adhered strictly to these criteria and therefore found only a few cases of olisthetic scoliosis

Brocher (3) accepted *Glorieux* s explanation as far as the rotation on the spondylytic gap on the contralateral side is concerned while on the mechanism of onset of the scoliosis he states This rotation has an unfortunate influence upon static function affecting one of the most vulnerable sites of the spine viz the lumbosacral junction

From a series of 115 patients with spondylolisthesis *Bosworth Fielding et al* (2) concluded that a clear relationship seems to exist between scoliosis in the lumbar spine and spondylolisthesis In their series 26 out of 115 patients or 23 % had some measure of scoliosis There was no relationship between the degree of olisthesis and the severity of scoliosis It is not mentioned whether these cases fulfilled the criteria of *Glorieux*

Among 75 patients with spondylolysis and spondylolisthesis under

20 years of age *Laurent & Einola* (7) found scoliosis in 27 i e 36 % No patient not even those with marked torsion showed signs of unilateral spondylolysis which according to the first publications by *Glorieux* is supposed to predispose to this condition

In an American series of 3 000 healthy males aged 18–65 years submitted to pre employment radiological examination of the lumbar spine *Allen & Lindem* (1950 (1)) found scoliosis in 0 5 % The degree of scoliosis is not stated and no mention is made of torsion These values are given for comparison with those mentioned above

PRESENT SERIES

The X ray films of all cases diagnosed as spondylolysis and/or spondylolisthesis from the time the Out patient Clinic was established in 1950 up to the end of 1961 were reviewed Sufficient radiographs was available for nearly all the patients and supplementary films were obtained of the remainder

The films of 261 patients were reviewed From this material 24 patients were excluded for the following reasons Some had been subjected to spondylodesis or hemilaminectomy and all having hemisacralization and spondylopseudolisthesis were ruled out in order to obtain a more pure series and exclude certain known causes of scoliosis

This leaves 237 patients distributed as follows

A Lumbar spondylolysis 62
B Lumbar spondylolisthesis 175

In both groups there are about twice as many males as females and the average age—at the time when the patient was first seen—was as shown in Fig 2

Table 1 corresponds to the usual finding i e that in about four fifths of all cases it is the fifth lumbar body which is involved

Table 2 shows that the great majority of patients had mild forms of spondylolisthesis If the severity of spondylolisthesis did increase with advancing age the average age would be expected to be highest for the Stage III and IV patients In the present series however these stages were represented only in very young patients

In analysing the cases of scoliosis the criteria of *Glorieux* were only partially observed In order to attribute the scoliosis to spondylolysis it



Fig 2

The patients average age at their first visit to the clinic. There are two summits in the 2. and in the 5.–6. decade representing the age when the olisthesis or the torsion appears and the age when the low back pain gives more severe trouble.

TABLE 1

Site of spondylolysis

	Fifth lumbar	Fourth lumbar	Third lumbar	Other vertebrae
Number of cases	183	60	6	1
Percentage	72.2 %	24 %	2.4 %	0.4 %

TABLE 2

Severity of spondylolisthesis

Meyerding's stages	No of males	No of females	*Total*	*In %*	*Average age*
Stage I less than 25 % slipping	71	42	113	64.6	44 years
Stage II 25–50 % slipping	33	20	53	30.3	43 years
Stage III 50–75 % slipping	4	2	6	3.4	28 years
Stage IV more than 75 % slipping	2	1	3	1.7	15 years

was demanded first that it was a true torsion scoliosis and secondly that the torsion had its maximum at the lytic or olisthetic vertebra. Therefore all cases of scoliosis unaccompanied by torsion and all cases in which the torsion had a maximum in another site are listed separately. Moreover cases having only torsion of the lumbar spine with a maxi-



Fig 3
A 45 year-old labourer The mildest form of torsion included in the series The oblique views disclo ed spondylol sis of the fifth lumbar body on both sides of the arch No spondylolisthesis

mum at the site of the spondylolytic body are given separately The torsion had to be indubitable the mildest cases included being of the order of magnitude illustrated in Fig 3 On the other hand no regard was paid to whether the spinous process on the olisthetic body was in alignment with the other spinous processes Frequently the spinous process of the fifth lumbar body is of an abnormal situation owing to all the transitional varieties to spina bifida which according to several authors (5 7 9) is of an increased incidence in patients with spondylolysis Moreover no regard was paid to whether the olisthetic body had sunk on the olisthetic side or on the contralateral side—which may occur too according to the present series Briefly as so called olisthetic scoliosis I included all forms of torsion scoliosis in the lumbar spine starting at the site of the olisthetic or lytic vertebra and decreasing upwards if no other causes of the scoliosis or torsion were demonstrable



Fig 4

A 55 year old smallholder. *Distinct torsion scoliosis. Other X rays disclosed bilateral* spondylolysis of the fifth lumbar body and spondylolisthesis of 36 %. In this case there is a question of asymmetrical slipping with simultaneous torsion and subsequent scoliosis.

According to Table 3 the incidence of torsion scoliosis among patients with spondylolysis and spondylolisthesis is about 30 %. It is evident also that among the patients with spondylolysis more than a quarter had distinct torsion. This torsion is so typical that whenever we observed it on an anteroposterior view, we did an oblique view of the lumbar spine. As yet, we are unable to submit the accurate frequency of spondylolysis in these cases, but we found it very often.

In *Taillard's* opinion the majority of the scolioses which do not fulfill the named criteria of *Glorieux* are due to pain. It seems to be a characteristic of pain induced scoliosis that as a rule it changes. It may be mentioned that in 10 cases we possess repeat radiographies after an interval of 1–6 years. All 10 patients are over 25 years of age and belong



Fig 5

A 5? year ld smallholder Di tinct torsion coli sis starting at the third lumbar l od In this case the lateral displacement is pronounced

TABLF 3

Frequency of torsion an l sc lios s in

A Fatients with pond l l sis

	Torsi n	T rs on l with imum t rsi n t th pon lyl lyt c rt bra	S ol o i with ut t rsion t m i mum t rs n in th r it
Female	5	f	2
Male	12	15	1
T tal	17	21	3
Fe cent	27	34 %	4 8 %

B Fatient with p ndyl li thesi

Female	1	20	7
Male	9	32	4
T tal	10	52	11
F r ent	5 %	30	6 3 %



Fig 6



Fig 7

Figs 6–7

Fig 6 Oblique view of the patient shown in Fig 5 A comparison with Fig 7 revealed that the slipping is asymmetrical i e a torsion Spondylolysis is present

Fig 7 Again the patient from Figs 5 and 6 in the opposite oblique projection On this side the forward slipping is not visible

to the group of spondylolisthesis Moreover we have repeat X rays of 6 patients having spondylolysis with torsion Neither the scoliosis nor the torsion had changed in any of these 16 cases This should be compared with the fact that in the present series as in most others it was not possible to demonstrate any definite increase in the degree of spondylolisthesis after the age of 25 apart from what may be due to an associated degeneration of the disc (*Friberg* (5) and others)

CONCLUSION

On the basis of the present series and upon studies of the literature it seems justified to establish that—apart from giving rise to olisthesis—lumbar spondylolysis may cause torsion of the lumbar column and that this torsion when attaining a severe degree or when olisthesis super

venes may give rise to scoliosis in the lumbar spine Thus this type of scoliosis may be classified among the osteogenic structural scolioses and is characterized as follows

1 On the X ray film it presents itself as torsion scoliosis the maximum torsion being at the lytic vertebra usually the lumbo sacral *junction*
2 As a rule it arises at the same time as the spondylolisthesis i e during the growth period
3 After its onset it undergoes practically no changes
4 The incidence in our series was about 30 % in a group of patients with spondylolysis and/or spondylolisthesis having low back pain

SUMMARY

Analysis of the X ray films of 237 patients with spondylolysis and/or spondylolisthesis revealed associated torsion scoliosis in about 30 %. The literature on this type of scoliosis is reviewed and the criteria summed up Moreover typical torsion of the lumbar spine was found *in 27 % of the patients with spondylolysis*

RÉSUMÉ

L analyse des radiographies de 237 malades souffrant de spondylolyse ou et de spondylolisthese a revele une scoliose associée dans environ 30 % des cas La littérature sur ce type de scoliose est passee en revue et il est donne un résume des critères Par ailleurs une torsion typique de la colonne lombaire a ete trouvee chez 27 % des malades souffrant de spondylolyse

ZUSAMMENFASSUNG

Die Analyse *von Rontgenfilmen von 237 Patienten mit* Spondylolyse und/oder Spondylolisthese zeigte eine damit verbundene Torsionsskoliose in ungefähr 30 %. Die Litteratur uber diese Skoliosetype wird durchgegangen und ihre Kennzeichen werden aufgezahlt Darüber hinaus wurde eine typische Torsion der Lendenwirbelsäule in 27 % der Patienten mit Spondylolyse gefunden

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EXPERIENCE IN WRIST JOINT ARTHRODESIS

A Follow up Investigation into 16 Operated Cases

By

LARS DANIELSSON and LARS UNANDER SCHARIN

INTRODUCTION

The most common indications for wrist joint arthrodesis are post traumatic—arthritic—and also neurological injuries The arthrodesis may be performed in various ways the radiocarpal approach alone and also in combination with intercarpal and carpometacarpal arthrodesis Various methods are described in the literature

Radiocarpal arthrodesis Smith Petersen s method with ulnar transplant + bone chips Seddon s method (a somewhat modified Smith Petersen)

Radiocarpal + intercarpal arthrodesis Abbott s method using an ileum graft + bone chips Liebolt s method only utilises bone chips from the ileum Brockman Nissen s method introduces tapered radius into both rows of carpal bones

Radiocarpal + intercarpal + carpometacarpal arthrodesis Colonna and Wickstroem introduce rib bone transplant into the radius carpus and metacarpals II and III Brittain s method utilises tibial transplant in the radius carpus and metacarpal III

In all methods excepting those of Brittain and Brockman Nissen cartilage resection takes place With the methods of Smith Petersen and Seddon primary resection of the distal ulna takes place

In the Orthopaedic Clinic in Harnosand 17 patients underwent wrist joint arthrodeses The series was followed up One patient had died during the intervening period and one patient had moved and could not be contacted Thus 15 patients were followed up 10 men and 5 women One woman was operated on bilaterally The series thus comprises 16 wrist joint operations Nine patients all right handed underwent operation on the left side The indications for operation can be seen in Table 1

Objective investigation

Clinically arthrodesis was present in 12 cases. Adjusting movements occurred in 3 patients, all with graft fracture. Two of these did not consider this slight instability to be troublesome. Total instability existed in 1 patient who had incurred infection postoperatively.

The position of the wrist was on average at 15° dorsal flexion. Three patients had 15° of radial deviation, one patient had 15° of ulnar deviation and the remaining wrists were in a mid position. Pro- and supination movements were normal apart from 3 patients (4 wrists). In 3 of these cases the distal ulnar fragment was not resected.

Finger mobility was normal in all cases except 3. These latter had neurological disturbances or rheumatic changes pre-operatively so that it is difficult to decide if the operation was the cause of the limited mobility.

The opponens function was normal in all cases except 1 (a patient with spastic hemiplegia). A reduction in sensibility on the dorsal side of the wrist within an area about 5 cms. wide around the operation scar was present in 5 cases. Otherwise no neurological disturbances caused by the operation could be observed. Shoulder and elbow mobility had not been affected in any case by the post-operative regimen. See Table II for dynamometer values.

DISCUSSION

There has been much discussion whether a stiff wrist joint is justified. In our series pain and deformity were so severe that we considered that the indications existed. After the operation the strength of the hand was not significantly reduced and the pro- and supination mobility remained by and large unchanged and in the majority of cases normal. The cosmetic result was also good.

Brittain's method was somewhat modified. Thus the cartilage resection was carried out radiocarpally and in the middle of the graft a notch was sawn out. This proved later to be unsuitable owing to the risk of graft fracture. A small lip can be sawn out of the graft instead in order to aid its insertion.

If there is a reduction in pro- and supination mobility or if the ulna is too long in the radiocarpal joint after resection, the distal fragment of the ulna must be resected.

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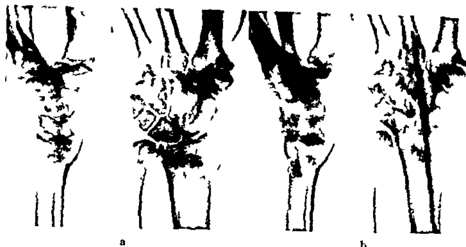


Fig. 1.
Malacia of the semilunar bone.
a. Before operation.
b. After operation.

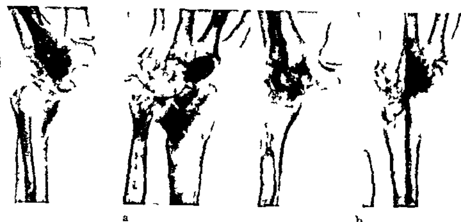


Fig. 2.
Rheumatoid arthritis.
a. Before operation.
b. After operation.

Operative technique. 13 wrist joints were operated on and tibia grafts were inserted in a chiselled groove in the radius, the carpus and also metacarpal III. Cartilage resection was performed in these cases radiocarpally but not intercarpally or carpometacarpally. The method is therefore a modified Brittain (Figs. 1 and 2). In 3 cases Abbott's method was employed (Fig. 3). The distal ulna was resected in 5 wrists.

The operation was performed in a closed field. Narcosis was used in



a b

Fig 3

Fracture of the navicular earlier operated on
a Before arthrodesis
b After arthrodesis

4 of the operations and plexus anesthesia in 12 In the later cases tibial grafts were taken under local anesthesia In conjunction with the operation a circular plaster was applied cut primarily and stretching from the elbow to the interphalangeal joint of the thumb indeed to the metacarpophalangeal joints of the fingers Re plastering and removal of sutures took place after 2 weeks The average period of fixation lasted 17 weeks

Postoperative complications were observed In one case wound infection occurred the transplant sequestrated and had to be removed 3½ months after operation A tibia fracture at the site of the graft was observed in one case 2½ months after the operation in conjunction with trauma Graft fractures were observed in 3 cases (in one case carpo metacarpally and in 2 cases in the middle of the transplant) Otherwise no postoperative complications were observed

Follow up investigation

12 of the patients stated that they were pleased with the results 3 were dissatisfied 4 of the 12 satisfied patients declared that they had slight aching after heavy work the other 8 (1 operated bilaterally) were completely free from trouble even with heavy work The 3 dissatisfied patients stated that they were subject to aching with light work

Working capacity

11 patients had returned to their old work Two patients had been trained in lighter occupations Two patients were incapable of working

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If there is a reduction in pro and supination mobility or if the ulna is too long in the radiocarpal joint after resection, the distal fragment of the ulna must be resected.

SUMMARY

17 patients with the diagnosis rheumatoid arthritis post traumatic arthrosis and paresis were operated on 15 patients with 16 operated wrist joints were followed up 12 patients were pleased and 3 displeased In 12 wrist joints osseous ankylosis and a good functional condition were achieved

RESUME

17 malades pour lesquels avaient ete poses les diagnostics arthrite rhumatoide arthrose post traumatique et paresie ont ete operes 15 malades avec 16 articulations du poignet operees ont ete suivis 12 malades etaient satisfaits et 3 mecontents Dans 12 poignets une ankylose osseuse et une bonne condition fonctionnelle avaient ete obtenues

ZUSAMMENFASSUNG

17 Patienten mit reumatischer Artritis post traumatischer Arthrosis und Paresen wurden operiert 15 Patienten mit operierten Handgelenken wurden nachuntersucht 12 Patienten waren zufrieden 3 nicht beschwerdefrei Bei 12 Handgelenken wurden knocherne Ankylose und eine gute Funktion erreicht

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FROM THE ORTHOPAEDIC CLINIC THE KAROLINSKA INSTITUTET STOCKHOLM (HEAD PROFESSOR STEN FRIBERG)

HEMANGIOMA OF THE KNEE JOINT

By

STEN KARLHOLM and JAN STJERNSWARD

Knee joint hemangioma may be the cause of pain lasting many years for which the correct diagnosis cannot be determined—often because the presence of synovial hemangioma is not brought into consideration Exploratory surgery is usually necessary for the diagnosis Among the relatively few cases in the literature the correct preoperative diagnosis was only established in exceptional cases During the period 1948 to 1961 three cases were treated at the Norrbacka Institute and reports of these are given below

Case No 1

6740 53 A woman aged 22 with an extremely tender site since the age of 17, 2 cms medial of the left patella with pronounced palpatory tenderness and hyper esthesia. She has had intermittent aching and slight swelling of 3 cms in extent above the area of tenderness The patient took part in physical exercise in school without restriction Relief was given by applying a firm elastic bandage over the knee There was no limitation of movement or painful movement in the knee joint No locking

Status General condition normal

Local status A small button shaped protrusion could be palpated on the medial side just above the joint of the left knee very tender on a level with the proximal edge of the capsule fold The range of motion was normal There was no difference in length of bone

Preoperatively a glomus tumour or meniscus ganglion was suspected Radiographic findings were negative

Operation Extra articularly nothing was found but a certain swelling of the capsule This was opened and a bluish black pocket like formation the size of a bean was encountered proceeding from the capsule This formation with the surrounding part of the synovial membrane was extirpated

Histology In sectioning fibrous tissue was seen in which lay a fairly well defined cavernous hemangiomatous tumour No glomus elements could be observed No basis for malignity or specific inflammation Cavernous hemangioma

Postoperatively there were no complications After 7 years observation there were still no symptoms

Case No 2

1894 48 A woman aged 34 with intermittent aching localized to the lateral side of the right patella for the last three years When bending the knee or after rising to her feet she experienced pain and she had difficulty climbing stairs She could not kneel down There was no locking It was not possible to ascertain trauma from the anamnesis Physiotherapy plaster immobilization and radiotherap had no effect

Status General condition normal

Local status Slight diffuse swelling of the right knee with contour maintained No exudate There was mu cle atrophy of the right thigh 1 cm in extent 15 cms proximally from the base of the patella Palpable capsule thickening and intense tenderness were found above the lateral femoral condyle There was no tenderness above the medial or lateral meni cus and ligaments The patella could be displaced laterally somewhat less to the right side than to the left

Preoperatively Radiographs and knee arthrographs were negative so that exploratory surgery was carried out

Operation An incision was made lateral to the patella In the fibrous capsule immediately adjacent to the patella a limited area of change was found 3–4 mms deep and with a diameter of 1 × 1 cm well vascularized and edematous An oval excision of the whole area was performed but the joint itself was not entered

Histology Loose connective tissue with rich vascularization Veins with obliterated lumen owing to a pronounced edematous intima Clo e by there were well defined clusters of cavernous blood filled vessels with thin walls A thin layer of connective tissue formed a cap ule like line of demarcati n Spread around these formations and other parts of the tissue numerous minor ves els were found generall con tracted with small lumina and partly conditioned by irregular proliferation of intima Here and there surrounding the vessels there was an abundance of lympho cytes and plasma cells Certain of the vessels were rich in nuclei and the cells had an epithelioid appearance and were directly joined t shrunken capillary angio matous parts surrounded by scanty smo th musculature There was no basis for malignant tumour or specific inflammation There was mainly cavernous hemangio matous formation

Postoperatively No complications No symptoms

Cas No 3

173? 61 A girl aged 13 with a 6 year anamnesis of intermittent aching above the right knee persisting the whole 24 hours and increasing after exertion The patient declared that the trouble probably commenced in connection with a severe blow to the right knee at the age of 6 Now an l again she experienced swelling above the right knee and noticed that there was ometime a click in the knee She had never had any locking The m ther occasionally ob erved a slight limp The patient had been examined b a number of doctors over recent years Repeated X ray examina tions had been negative and the di ease remained undiagnosed

Status General c nditi n n rmal Asthenic build

Local status No obvious limp Con iderable quadriceps atrophy existed in the right leg equal to 4 5 cms at a di tance of 12 cms., above the base of the patella. The range of movement in the knee joint was 180–50 degrees Distinct and

intense palpatory tenderness was present in an area 2 × 2 cms in size and 3 cms proximal and medial from the base of the patella No hydrops No instability The right leg was 1 cm shorter than the left measured from the anterior superior iliac spine to the upper margin of the medial malleolus Reflexes and sensibility were normal Skin colour was average The knee X rays showed a normal picture

Preoperatively a glomus tumour or chondromalacia of the patella with chronic bursitis was suspected After applying a knee plaster for two weeks there was no change and an arthrotomy was decided

Operation A well defined capsular hemangioma the size of a plum was extirpated it proceeded from the proximal synovial membrane upwards against the vastus medialis muscle

Histology In the section fatty and connective tissue groups of dilated vessels were seen with very thin fibrous walls The architecture of the vessels was cavernous There was no basis for malignancy The preparation was considered to be an angiomatous formation with cavernous structures

Postoperatively At the check up after 4 months the girl was free from pain without palpation tenderness and possessed good mobility 180–60 degrees A quadriceps atrophy of 2 5 cms was present 15 cms above the base of the patella The patient who was previously nervous and complaining is now according to the father happy and lively

DISCUSSION

The 3 related cases all had intermittent aching and swelling palpatory capsular thickening and distinct palpatory tenderness Quadriceps atrophy was measured in 2 patients Two of the cases experienced the first trouble at the early ages of 6 and 12 years They all had a long case history 3 6 and 10 years before the correct diagnosis was made Knee radiographs showed normal conditions

When studying earlier cases reported in the literature the above details were found to be typical of a knee joint hemangioma Trouble was experienced at an early age (3 4 6 8 9 12 16 19 27 36) and usually the patients had suffered for several years before the correct diagnosis could be made (1 3 4 9 12 16 17 19 21 27) *Weaver* (1938) emphasizes that no benign tumour with the exception of the glomus tumour causes aching as often as hemangioma The quadriceps atrophy (4 9 17 19 21 31) was seen to be a normal clinical finding A palpable tumour occurred in about half of the cases and then was often diffusely palpable A markedly palpable tumour diminishes on elevation of the leg Bone lenght disturbances were observed by some authors with increased growth in length in two out of nine cases (19) The occurrence of increased bone length in hemangioma is stressed by *Weaver* Extremely few cases of knee joint hemangioma were correctly diagnosed preoperatively Preoperatively a number of diagnoses were made such

as chronic bursitis glomus tumour chondromalacia patellae growing pains loose body the hemarthrosis gc arthritis lues and meniscus injury

Radiography did not give any guide to the diagnosis Puncture of the tumour with the exchange of blood and diminished swelling on elevation may result in some guidance (11 21 31) Angiography may be a valuable measure in obtaining a preoperatively diagnosis (2 17) but is sometimes negative owing to thrombosis preventing suitable contrast filling (6 15)

The etiology is unknown The majority of authors accept the theory of a congenital anomaly where the symptoms often begin in connection with trauma (3 4 6 16 17 21 31)

Therapy dependes on the spread of the hemangioma With stalk hemangioma the result is good when the tumour is excised With diffusely spread hemangioma *Bennet & Cobey* recommended X ray therapy without any attempt at excision

SUMMARY

Three cases of hemangioma of the knee joint are reported Intermittent pain and palpabel tenderness were the main symptoms together with atrophy of the quadriceps muscles and local swelling

Surgical exploration determined the diagnosis and the excision of the pedunculated tumour afforded complete relief

RESUME

Trois cas d hémangiome de l articulation du genou sont rapportes Les principaux symptomes cliniques étaient des douleurs intermittentes l enflure l atrophie des muscles quadriceps et une sensibilite douloureuse palpable

L exploration chirurgical établit le diagnostic et l excision de la tumeur pedonculée assura un complet soulagement au malade

ZUSAMMENFASSUNG

Drei Fälle von Haemangiome des Kniegelenkes werden berichtet Die klinischen Hauptsymptome waren intermittierende Schmerzen und Swellung Atrophie des m quadriceps und Druckempfindlichkeit

Die chirurgische Freilegung gab die Diagnose und die Entfernung des gestielten Tumors brachte vollständige Heilung

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CONGENITAL PSEUDARTHROSIS OF THE TIBIA

By

M SULAMAA and P VILKKI

Congenital pseudarthrosis of the tibia is a rare clinical entity resistant to all forms of therapy during infancy and early childhood *Knight* (1) classifies the cases into three types 1 defect of the mid tibia at birth 2 fracture associated with a congenital cyst of the tibia and 3 fracture associated with congenital bowing of the tibia The third group is probably the rarest and forms a curious entity for which no underlying cause of the weakness of the tibia can be discovered A minor trauma or corrective osteotomy for bowing results in pseudarthrosis in which union is most difficult to secure—even more difficult than in the other forms of congenital pseudarthrosis (2) The published data (1 2 3 4) show that union if obtained in this condition is often accompanied by considerable deformity and shortening of the leg Although rare the disease merits the attention of clinicians since the consequences to the child if treatment is not adequate are most serious amputation of the leg being by no means infrequently the end result (2)

The purpose of this paper is to describe those cases of congenital pseudarthrosis of the tibia treated in this hospital in which the weakness of the bone is really idiopathic in nature and not due to a tumour or cyst or to a macropscopic defect In all our three cases the tibia was too weak to allow normal weight bearing from the beginning and the pseudarthrosis became manifest when the patient first began to walk *The history of bowing of the leg was apparent from birth In one case* the pseudarthrosis was not present when the patient was first seen in this hospital but resulted from a corrective osteotomy for severe bowing of the tibia

CASE REPORTS

Case 1 R S a boy with a curved left leg took his first steps at the age of 14 months A very slight trauma resulted in swelling and ten



Fig 1

Case 1 Age of the patient and operations performed are indicated below the X ray pictures Operation numbers relate to table 1

derness of the leg and the patient was admitted to the local hospital There an old fracture of the left tibia was diagnosed The bowing at the site of the fracture was corrected by open reduction and the limb immobilized in a plaster cast Despite long and effective immobilization no union occurred

The boy was first seen at this hospital at the age of two years X ray examination (Fig 1) showed a typical picture of pseudarthrosis in the left tibia between the middle and lower thirds of the bone At operation (Oper 2 Table 1) the fibrous pseudarthrosis was removed and the contralateral fibula transfixed like an intramedullary nail across the defect Biopsy showed fibrous connective tissue with islets of hyaline cartilage there being no sign of normal bone formation The first bone grafting failed but five grafting operations over the next six years gradually resulted in bony union (Table 1) The growth of the leg was not arrested by the disease or by the grafting operations (Table 2) The boy is now walking with the aid of a light leather brace

TABLE 1

No and type of operation	Age years	Result
Case 1		
1 Open reduction Fragmentation	1	absorption of bone pseudarthrosis
2 Resection of pseudarthrosis Fibular autograft	2	absorption of graft pseudarthrosis
3 Costal dual onlay auto and homograft	2¼	absorption of grafts pseudarthrosis
4 Resection of pseudarthrosis Ileal crista autograft	3	bony union through callus at first later refracture
5 Costal homograft with intramedullary nailing	4	partial bony union
6 Costal autograft	5½	absorption of graft reappearance of fracture
7 Long costal by pass autograft	7	bony union of tibia and grafts
Case 2		
1 Closed reduction Plaster cast	1	pseudarthrosis
2 Fibular autograft	1½	partial bony union reappearance of fracture at mobilization
3 Resection of pseudoarthrosis Fibular autograft	2½	callus formation later fracture through callus
4 Costal homograft	4	partial bony union bowing of tibia
5 Long costal by pass homograft	7	partial bony union of tibia fracture line through graft
Case 3		
1 Tibial osteotomy dual onlay costal homograft	1	absorption of grafts pseudarthrosis
2 Long costal auto and homografts by pass	1½	first incorporation later fracture of grafts
3 Long costal homografts by pass	2	bony union of grafts defect of tibia

Case 2 J H a boy aged 14 months Shortly after learning to walk he fell from a low footstool hurting his left leg He was immediately admitted to this hospital X ray (Fig 2) showed an old fracture of the left tibia with bowing below the site of the fracture Closed reduction

TABLE 2
Length of both tibiae in cm

Age years	Case 1		Case 2		Case 3	
	d	sin	d	sin	dx	sin
1	13.9	13.7	13.9	13.7	14.5	14.2
2	14.0	13.5	15.7	15.8	17.4	17.2
3	17.3	16.5	18.1	18.2		
5	22.4	22.5	23.2	23.3		
7	24.3	24.2	27.6	27.6		
difference in length	—0.1		0		+0.2	

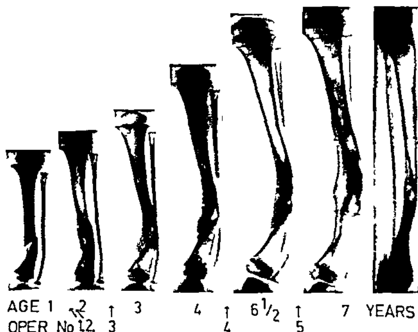


Fig 2
Case 2 Age and operations as indicated in Fig 1

TABLE 1

No. and type of operation	Age years	Result
Case 1		
1 Open reduction. Fragmentation	1	absorption of bone, pseudarthrosis
2 Resection of pseudarthrosis. Fibular autograft	2	absorption of graft, pseudarthrosis
3 Costal dual onlay auto- and homograft	2½	absorption of grafts, pseudarthrosis
4 Resection of pseudarthrosis. Ileal crista autograft	3	bony union through callus at first, later refracture
5 Costal homograft with intramedullary nailing	4	partial bony union
6 Costal autograft	5½	absorption of graft, reappearance of fracture
7 Long costal by-pass autograft	7	bony union of tibia and grafts
Case 2		
1 Closed reduction. Plaster cast	1	pseudarthrosis
2 Fibular autograft	1½	partial bony union, reappearance of fracture at mobilization
3 Resection of pseudoarthrosis. Fibular autograft	2½	callus formation, later fracture through callus
4 Costal homograft	4	partial bony union, bowing of tibia
5 Long costal by-pass homograft	7	partial bony union of tibia, fracture line through graft
Case 3		
1 Tibial osteotomy, dual onlay costal homograft	1	absorption of grafts, pseudarthrosis
2 Long costal auto- and homografts, by-pass	1½	first incorporation, later fracture of grafts
3 Long costal homografts, by-pass	2	bony union of grafts, defect of tibia

biopsy specimen from the second operation small pieces of bone embedded in scar like connective tissue were seen To-day a bony union of the grafts is apparent There is however a cystic defect of the tibia proper and she is still wearing a walking plaster cast



Fig 4
Photograph of the legs of case 3 before the first operation

DISCUSSION

The three cases of congenital tibial pseudarthrosis described required multiple bone grafting operations before a bony union was achieved In spite of the multiple operations—or perhaps thanks to them—a gross deformity of the bone was avoided and no arrest of the normal growth of the leg occurred As bony union was secured at the age of 7 in two of the cases and at the age of 2 in the third there will be ample time for the normal growth of the bone to correct the residual minor deformities The great tendency to recurrence of childhood pseudarthrosis is well known Therefore a light brace to protect the leg from external trauma is still continued in all cases Despite the brace the children are able to undertake fairly normal physical activities

In our cases the source of the bone used in the grafting operations seems to have been of minor importance Fibula ileal crista and ribs from the patients themselves were used as autografts Frozen ribs from the bone bank as well as fresh homografts were also used Long bypass grafts bridging far beyond the pseudarthrosis on each side seem to be incorporated more readily than short onlay grafts or intramedul

lary grafts Long by pass grafts of *McFarland* (4) type were preferred at the latest operations No attempt was made to remove the fibrous pseudarthrosis tissue since this might have jeopardized the endeavour to maintain the normal length of the bone Although well incorporated at the ends the by pass grafts also showed a great tendency to fracture at the original site of the pseudarthrosis The tendency to fracture at this magic level even in the opposite leg is curiously demonstrated by the two patients in whom the contralateral fibula was used as grafting material Both of these developed a pseudarthrosis at the exactly same level of the otherwise normally regenerating contralateral fibula

Intramedullary nail fixation was used only once in our cases No other internal fixation devices were employed except suturing of the onlay grafts with wire We feel that internal fixation as recommended by some authors (2 4 5) has little value in these cases provided that efficient grafting procedures are begun early enough to prevent the development of gross deformity

As is known from the literature (1 2) the prognosis of bone grafting in congenital pseudarthrosis becomes better and better with the growth of the child If a more or less normal leg can be maintained until puberty a good result is the rule Unfortunately serious deformity and shortening of the leg is often so evident even at preschool age that amputation has to be resorted to We feel that our active attitude to regrafting as soon as the previous graft shows signs of failure is of the utmost importance in preventing the deformity and shortening Also by frequent regrafting advantage is taken of the earliest possible moment for the bone consolidation as conditions gradually become favourable for union The age of possible consolidation must vary from patient to patient otherwise the unpredictable results of the same grafting procedure at various ages and in different patients are incomprehensible

These cases of ours like other series in the literature show clearly enough that a leg with congenital pseudarthrosis can be restored to normal function and length by careful surgical management The failures too often encountered may be largely avoided if the disease is diagnosed early and the treatment planned with all the thoroughness demanded by these very difficult cases

SUMMARY

Three cases of congenital pseudarthrosis of the tibia treated with multiple bone grafting operations are described The result of the treat

ment in all three cases is a stable leg of normal length None of the cases has yet reached skeletal maturity

RESUME

Trois cas de pseudarthose congenitale du tibia traites par des opera tions de multiples greffes osseuses sont decrits Dans les trois cas le resultat du traitement a ete une jambe stable le longueur normale Dans aucun des cas la maturite squelettique n est encore atteinte

ZUSAMMENFASSUNG

Drei Falle von angeborener Pseudarthrose der Tibia die mittels wiederholten Knochensprangenoperationen behandelt wurden werden beschrieben Das Ergebnis der Behandlung ist in allen drei Fällen ein stabiler Unterschenkel von normaler Länge Keiner der Fälle hat noch Skelettvollreife erreicht

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FROM THE KRONPRINSESSE MARTHAS INSTITUTT OSLO
(HEAD H S NISSEN LIE M D)

THE AXIS OF THE ANKLE JOINT AND ITS IMPORTANCE IN SUBTALAR ARTHRODESIS[1]

By

THOMAS WALLER

The direction of the axis of the ankle joint is described somewhat variously in the literature but generally it is described as almost entirely transverse in relation to the sagittal plane of the normal foot

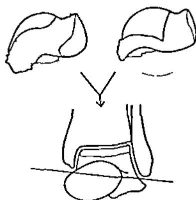
Barnett Napier & Hicks examined the axis of the ankle joint in greater detail *Barnett & Napier* examined 152 cartilage covered talus bones and found that the medial profile of the trochlea is composed of an *anterior* arc with a small radius and a posterior arc with a large radius while the lateral profile consists of a single arc with a medium sized radius (Fig 1)

In moving the foot dorsally to the O position (both in the dorsal and plantar direction *in this dorsal area of movement) it is the anterior* part of the trochlea with the sharp medial arc which is in contact with the tibia From this *Barnett & Napier* concluded that these movements must occur around an axis which is higher medially than laterally *(Fig 1 a) The reverse in the case with movements plantar to the O posi*tion (both in the plantar and dorsal direction in this plantar area of movement) now it is the posterior part of the trochlea with the slack medial arc which is in contact with the tibia These movements must *therefore occur around an axis which is lower medially than laterally* (Fig 1 b)

The oblique position of both axes in relation to the horizontal plane varies amongst individuals

The extent of the variation in breadth is not stated directly in Barnett & *Napier's* work but from graphs it appears that the obliquity of the axis for the plantar area varied from 0 to 16 and that the obliquity

1 Reprinted after correction from The Proceedings of the Nordisk Orthopedisk *Forenings 30th Assembly in Oslo where the article contained some confusing errors*



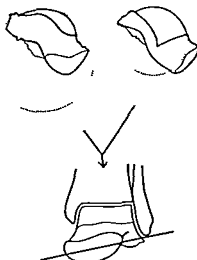


Fig 1 A *Fig 1 B*

Figs 1 A and 1 B

The medial profile of the trochlea tali is composed of an anterior curve with a small radius and a posterior curve with a large radius The lateral profile consists of a single curve of medium sized radius Movements of the foot dorsally to the O position therefore occur about an axis that is higher medially than laterally (1 A) and movements plantar to the O position occur about an axis that is lower medially than laterally (1 B) For clarity the lateral side of (the left) talus is given in mirror reflection (*Barnett & Napier* 1952 Reproduced from the Journal of Anatomy with kind permission of the editor and of the authors)

of the axis for the dorsal area in selected groups totalling 83 bones varied from 0 to 14

Hicks examined the movements in the ankle joint by means of 9 presumably normal preparations The soft tissue of the preparations was preserved up to 4 cms above the ankle joint The movements were produced by pulling on the tendons both with and without weight bearing by the foot

Hicks also found 2 axes one for the dorsal and another for the plantar area of movement The axes had the same direction of inclination relative to the horizontal plane as *Barnett & Napier* had calculated More over *Hicks* found that both axes passed obliquely in relation to the frontal plane of the foot as the medial end of both axes pointed somewhat ventrally On *Hicks* illustration (Fig 2) I have measured the horizontal projection of the divergences of the axes from the frontal plane and found it to be 14 and 17 (The frontal plane is thought to be at right angles to the longitudinal axis of the foot On Fig 2 the

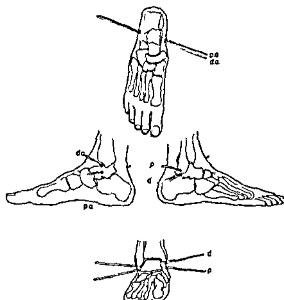


Fig 2

Axes of ankle joint p a = axis of movements plantar to O position d a = axis of movements dorsal to O position (*Hicks* 1953 Redrawn from the Journal of Anatomy with kind permission of the editors and the authors)

horizontal projection of the foot is shown in slight abduction so the *oblique position of the ankle axes appears larger still)*

As clinical landmarks *Hicks* states that the axis of the dorsal area of movement passes from a point 1½ cms in front of the tip of the medial malleolus to a point ½ cm below the tip of the lateral malleolus and that the axis of the plantar area passes from a point 1½ cms in front of the tip of the medial malleolus and 1 cm below it to a point ½ cm above the tip of the lateral malleolus

The fact that the ankle axis passes obliquely instead of at right angles to the sagittal plane of the foot means that the foot moves in the ankle joint like a badly mounted wheel If we imagine the sagittal plane of the foot to be a round disc with the ankle joint in its centre and the ankle axis mounted obliquely the disc will wobble from side to side in its movements around the axis (Fig 3) If we regard the tip of the foot we call this swerve abduction adduction if we regard the heel (represented by a cranio caudal line of direction) we call this swerve valgus varus A model like that in Fig 3 wobbles regularly The swerve of the foot becomes irregular because the ankle axis changes direction when the O position is passed





Fig 3 A Fig 3 B

Figs 3 A and B

The sagittal plane of the foot may be regarded as a round disc with the ankle joint in the centre and the axis of the joint oblique (3 A) On movement about its axis the disc will wobble like a poorly mounted wheel (3 B)

Normally the swerve of the ankle joint is compensated as required by opposing movements in the talo-tarsal joints so that the swerve is difficult to detect When subtalar arthrodesis has been performed however this compensation mechanism is annulled and the swerve comes to light This means that the foot after performance of subtalar arthrodesis places itself in different degrees of varus or valgus according to the different degrees of height of the shoe s heel

The extent of the swerve normally varies according to the individual In a pathological series which feet with subtalar arthrodesis certainly form the variation must be assumed to be larger than normal This must already be accepted for the reason that even if the axis passes normally in relation to the malleoli and the talus then a malposition of the heel will produce an abnormal position between the axis and the *median plane of the heel with a consequent abnormal swerve of the heel*

Figs 4–11 show some examples of how 4 cms lift of the heel influences the valgus varus position of the heel when subtalar arthrodesis has been carried out The individual variation is as can be seen considerable from no swerve (Fig 6) to considerable swerve in the varus direction (Fig)) None of the examples show swerve in the valgus direction nor can I remember seeing such a swerve at any time in

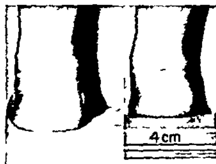


Fig 4
Man aged 48 Left foot He had had poliomyelitis as a child and triple arthrodesis as an adult The slight varus position with a support of 4 cms under the heel made the foot so unsteady that he could not use this height of heel which would have been desirable because of shortening of the leg



Fig 5
Girl aged 1? Right foot Poliomyelitis *arthrodesis a m Grice Shortening of the* leg made a 4 cms heel desirable so that the arthrodesis may be regarded as being in ideal position despite considerable valgus barefooted

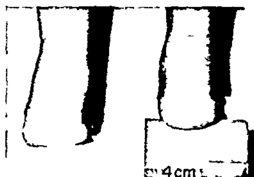


Fig 6
Girl aged 13 Left foot P li myelitis arthrodesis a m Grice



Fig 7
Girl aged 10 bilateral idiopathic pes plano valgu bilateral ar thrcdesis a m Grice



Fig 8
Man aged 43 Left foot Cavo varus
triple arthrodesis
No appreciable swerve



Fig 9
Woman aged 48 Left foot Calcaneus
fracture triple arthrodesis



Fig 10
Boy aged 11 years Right foot Pes valgus after
division of tendon of anterior tibial muscle
arthrodesis a m Grice



Fig 11
B y aged 13 ear Charc t Marie Tooth s di ea e bilateral triple arthr desi

plantar flexion. The swerve seems to be particularly prominent in patients who had polio as children (Figs. 4, 5, 6).

Now it is the case that the varus position is endured much less easily than the valgus position, not least by polio patients.

The conclusion is therefore that in the adjustment of a subtalar arthrodesis on the operation table consideration *must be given to the degree of plantar flexion* which it is desirable for the patient to carry out without the foot assuming a varus position. In other words consideration must be given to the height of heel which the patient will require in his footwear after the operation, with a slight addition for walking down hills. The height of the heel may be determined by cosmetic wishes or by shortening of the extremity.

Allowance for the height of the heel is most simply achieved by undertaking the adjustment of the arthrodesis with the ankle joint in the pointed foot position which the desired heel height requires and *not at right angles between leg and sole of foot.*

With this procedure one does not need to know how large or small is the patient's swerve in the ankle joint. If the swerve is large the foot places itself in a deforming valgus position when walking barefoot (Fig. 5), but this must be said to be of minor importance in this connection. It is the price the patient must pay to walk comfortably and neatly with shoes on. If the swerve is small, the fact that the subtalar adjustment is undertaken with the ankle in the pointed foot position will not very much affect the position of the foot when walking barefoot (Fig. 8). It may be accepted that this procedure is more reliable than, with the ankle at right angles, the haphazard adjustment of the arthrodesis to some degree of valgus position in order to compensate for the unknown large swerve in the varus direction caused by the shoe heel.

SUMMARY

Barnett, Napier & Hicks showed that the axis of the ankle joint passes obliquely in relation to the sagittal plane of the foot. This means that the foot moves in the ankle joint like a poorly mounted wheel: it swerves from side to side. Normally the swerve is compensated for in the talotarsal joints, but when subtalar arthrodesis has been performed there is no compensation. The size and variability of the lateral swerve of the heel in a plantar flexion corresponding to a shoe heel of 4 cms is demonstrated. In all the cases demonstrated the heel swerves in the varus direction on such plantar flexion, if it does swerve at all.

Varus is endured less easily than valgus The conclusion therefore is that in adjusting a subtalar arthrodesis on the operating table consideration must be given to the height of the heel the patient is to use (e g owing to shortening of the extremity) This is done by adjusting the subtalar arthrodesis with the ankle joint in the pointed foot position which the height of the heel requires and not at right angles between leg and sole of foot

RESUME

Barnett, Napier & Hicks ont montre que l axe de l articulation de la cheville est incline par rapport au plan sagittal du pied Cela signifie que le pied se meut dans l articulation de la cheville comme une roue mal montee qui est «projetee» d un cote a l autre Normalement la projection est compensee dans les articulations talotarsiennes mais dans l arthrodèse sous astragalienne elle n est pas compensee Il est fait la démonstration de l importance et de la variabilite de la projection de cote du talon lorsque la flexion plantaire correspond a un talon de chaussure de 4 cm de hauteur Dans tous les cas indiques le talon est projete en direction varus a cette flexion plantaire s il est projete

On supporte moins bien la position varus que valgus C est pourquoi on en conclut qu au moment d etablir l arthrodese sous astragalienne sur la table d operation il convient de tenir compte de la hauteur du talon que portera le malade (par ex par suite d un raccourcissement de l extremite) On le fait en adaptant l arthrodese sous astragalienne a l articulation de la cheville dans la position du pied indiquée par la hauteur du talon de la chaussure et non a angle droit entre la jambe et la plante du pied

ZUSAMMENFASSUNG

Barnett Napier & Hicks haben nachgewiesen dass die Achse des Knochelgelenkes im Verhaltnis zur Sagittalebene des Fusses schrag verlauft Das bedeutet dass der Fuss sich im Knochelgelenk wie ein schlecht montiertes Rad bewegt er wirft sich von Seite zu Seite Normalerweise wird dieses Werfen in den Talotarsalgelenken kompensiert aber nach einer subtalaren Arthrodese geht keine Kompensation vor sich – Die Grosse und Variation der Fersenablenkung bei einer Plantarflexion die einer Absatzhohe von 4 cm entspricht wird demonstriert In allen den vorgezeigten Fallen wird die Ferse bei einer solchen Plantarflexion in der Varusrichtung abgelenkt wenn eine Ablenkung uberhaupt stattfindet

Eine Varusstellung wird schlechter vertragen als eine Valgusstellung. Man schliesst daher, dass man bei der Anpassung einer subtalaren Arthrodese am Operationstische Rücksicht auf die Absatzhöhe nehmen muss, die der Patient späterhin brauchen soll (z. Bsp. wegen Gliedmassenverkürzung). Das geschieht, indem man die Subtalararthrodese mit dem Knöchelgelenk in der Spitzfussstellung zusammenpasst, die die Absatzhöhe erfordert, und nicht im rechten Winkel zwischen Unterschenkel und Fusssohle.

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PROPHYLACTIC ANTICOAGULANT THERAPY IN THE TREATMENT OF LOWER LIMB FRACTURES

By

KALKO A SOLONEN

The present paper is concerned with a clinical study of the value of anticoagulant phophylaxis in patients with fractures The aim was also to try to evaluate the effect of the anticoagulant on the healing of the fractures The trial was restricted to a group of fracture patients susceptible to tromboembolic complications Phophylaxis must consequently be regarded as justified especially as the methods employed and the laboratory control of treatment are routine hospital work

The idea of this study was given by my chief who became interested in the subject after reading the excellent paper of *Sevitt & Gallagher* (1959) Their material consisted solely of patients with fractures of the femoral neck and the anticoagulant used was phenindione They established a sharp decrease in the incidence of venous thrombosis and pulmonary embolism in patients given prophylactic treatment but they failed to mention the effect of prophylaxis on the healing of the fractures The healing of fractures in experimental animals given anticoagulants was studied e g by *Stinchfield et al* (1956) who found that both ante- and postoperatively administered anticoagulant therapy (Heparin and Dicumarol) delay the healing of an experimental fracture of the os ileum (cancellous bone) The same observation was made by *Minolla et al* (1958) in their study of the effect of heparin and dicumarol on the healing of fractured rabbit radius

Sevitt et al reported pulmonary embolism in c 20 per cent of the autopsies in the Birmingham Accident Hospital and it was the cause of death in 14 per cent of the total series and as much as 40–50 per cent of "elderly patients who died after a fractured femur tibia or pelvis Further thrombosis of deep veins of the lower limbs was established in over 80 per cent of elderly patients who died after a fractured femur

Pulmonary embolism was reported by *Hermann et al.* (1961) in 0.94 per cent of operatively treated patients. They are convinced of the benefit of anticoagulant prophylaxis. In 4 391 autopsies *Coon et al.* (1959) established pulmonary emboli in 606 cases (13.8 per cent); they were the cause of death in 198 cases. *Marks et al.* (1954) estimated that in a busy hospital of 500 beds an average of 10 fatal pulmonary emboli will occur each year.

Series

The series consisted of patients aged 40 or over with one of the lower limb fractures listed in Table 1.

TABLE 1
Material

Diagnosis	Anti coagulant group	Control group	Total
Fracture of the femoral neck	20	22	42
Trochanteric fracture	16	16	32
Fracture of the shaft of the femur	17	15	32
Fracture of the shaft of the tibia (and fibula)	36	36	72
Total	89	89	178

The distribution by sex varied in the different groups but the total female : male ratio was c. 5 : 3.

METHOD

Collection of the material

To achieve the greatest reliability possible in the comparison between the prophylactic group and the control group the subjects for each group were taken from patients admitted at the same time to the clinic. Every other patient aged 40 or over who was admitted for treatment for the fractures mentioned in Table 1 was included in the prophylaxis group and every other patient in the control group. However, some transfers had to be made from one group to the other, e.g. in cases with a contraindication for the use of an anticoagulant agent. All transfers from one group to the other or omissions from the total series (e.g.

moving to another hospital) were offset by a corresponding transfer or omission from the other group Otherwise however the series is completely unselected

The collection of the series was *commenced in spring 1960 and ended* in autumn 1961

The trial

Phenylindandione (Trombosol Star 0 05 tabl) was the anticoagulant employed in the present study The initial phenylindandione dose 150–300 mg was selected as individually as possible At the beginning of the trial the anticoagulant was administered from the post traumatic or post-operative day but half way through it the phophylaxis was changed and was begun only on the 5th post traumatic or post operative day The change was not because of complications but simply in an effort to achieve the greatest possible elimination of detrimental effects Contraindications to anticoagulant therapy were sought at the outset on the basis of preliminary data and subsequent investigation The appearance of haemorrhagic and thromboembolic complications in both groups was established at the earliest possible stage and managed accordingly and independently of the study in question The phenylindandione dosage was controlled frequently by the Thrombotest method (Owren) The Thrombotest value was kept at 10–25 per cent as far as possible In the absence of any impediment the anticoalugant therapy was continued until the patient was mobilised satisfactory or discharged

An analysis of some prognostically important characteristics of the patients shows e g that c 62 per cent were in good and c 12 in poor condition on admission 18 per cent were complicated by obesity 2 per cent were incapable of walking before the accident 18 per cent were in poor mental condition (senile alcoholic dementia sequela of apoplexy psychosis etc) 21 per cent had hypertension of varying degree (systolic blood pressure over 170 mm Hg) another 21 per cent had cardiac failure of varying severity 17 per cent had cardiosclerosis 3 per cent had post apoplectic hemiparesis or hemiplegia 8 per cent had varicose veins in the lower limbs

The methods of treatment were the conservative or operative procedures commonly used at the clinic When operation was decided if anticoagulant prophylaxis had been initiated it was discontinued and the patient was given vitamin K_1 on the day preceding the operation

and on the day of the operation itself Prophylactic phenylindandione treatment was started again after the operation according to the schedule followed primarily

The results of the investigation

TABLE 2
Clinically established thrombosis of the deep vein of the lower limb

Fracture	Phenylindandione group		Control group	
	Size of the group	Thrombosis established	Size of the group	Thrombosis established
Fracture of the femoral neck	20	–	22	4
Trochanteric fracture	16		16	5
Fracture of the shaft of the femur	17	–	15	1
Fracture of the shaft of the tibia (and fibula)	36		36	4
Total	89	–	89	14

The relative incidence of venous thrombosis of the lower limbs of the phenylindandione group was thus 0 and of the control series 16 per cent

TABLE 3
Clinically established cases of pulmonary embolism (with or without diagnosed thromboses)

Fracture	Clinically established venous thrombosis (from Table 2)		Cases of pulmonary embolism			
			Patients with venous thrombosis		Patients without venous thrombosis	
	Phenylindandione group	Control group	Phenylindandione group	Control group	Phenylindandione group	Control group
Fracture of the femoral neck		4		2	1	1
Trochanteric fracture		5				1
Fracture of the shaft of the femur		1				1
Fracture of the shaft of the tibia (and fibula)		4				2
Total		14		2	1	5

The thromboembolic complications established were treated routinely including the use of anticoagulants and independently of the investigation

TABLE 4

Arterial thromboses of the heart and systemic circulation

Fracture	Coronary thrombosis		Cerebral thrombosis		Mesenterial thrombosis		Thrombosis of the femoral artery	
	Phenylindandion group	Control group	Phenylindandion group	Control group	Phenylindandion group	Control group	Phenylindandion group	Control group
Fracture of the femoral neck	–	2	–	2	–	–	–	–
Trochanteric fracture	–	–	–	–	–	1	–	–
Fracture of the shaft of the femur	–	1	–	–	–	–	–	1
Fracture of the shaft of the tibia (and fibula)	–	–	–	–	–	–	–	–
Total	–	3	–	2	–	1	–	1

TABLE 5

Other complications

Fracture	Haemorrhage (melaena, haematuria)		Decubitus		Pneumonia		Wound infection		Fat embolism	
	Phenylindandion group	Control group	Phenylindandion group	Control group	Phenylindandion group	Control group	Phenylindandion group	Control group	Phenylindandion group	Control group
Fracture of the femoral neck	1	1	1	1	–	3	–	–	–	1
Trochanteric fracture	1	–	2	2	2	2	–	1	–	–
Fracture of the shaft of the femur	1	–		1	–	–		–	–	
Fracture of the shaft of the tibia (and fibula)	–		1	1	2	–	–	–	–	–
Total	3	1	4	5	4	5	–	1	–	1

Minor rapidly healed wound infections were disregarded

Pulmonary embolism was stated in c 1 per cent of the anticoagulant prophylaxis group and in c 8 per cent of the controls Only the cases with a diagnosis that was considered certain were included in the calculation

The age of these patients was 48–89 years (average 69) The general condition was assessed as good in only one case Only one of them died and the diagnosis of embolism was confirmed at autopsy

The haemorrhagic complications were significant in only one case described in more detail in connection with Table 6 The haemorrhage was an indication for the discontinuation of anticoagulant therapy in all 3 cases of the phenylindandione group Furthermore one of the controls also developed a fairly mild but manifest melaena for reasons which remained obscure (Cf *Hemley et al* 1961)

TABLE 6
Causes of death

Main causes of death	Secondary causes	Phenylindandione	Controls
Pulmonary embolism	Pneumonia	–	3
Bronchopneumonia	Pulmonary embolism	1	–
	Heart disease	–	1
	Diabetes	–	1
	Melaena	1	1
Hypertension	Heart failure	2	1
	Mesenterial thrombosis	–	1
Carcinoma		1	
Other causes		1	
	Total	6	8

An infirm woman of 74 who was found at autopsy to have minor thromboses of the pulmonary artery

A woman of 83 who died of diabetic coma No autopsy was performed

A woman of 79 who showed neither anamnestically nor clinically contra indications for the use of anticoagulants Was given only 495 mg of phenylindandione altogether in 3 days The Thrombotest value fell to 4 Autopsy established in addition to bronchopneumonia also definite haemorrhagic enteritis colitis and cystitis probably caused by the anticoagulant

One of these patients a woman of 67 had in addition purulent cholecystitis and gangrenous (*not* haemorrhagic) cystitis

A woman of 87 who was gradually prostrated Senile exhaustion No autopsy was performed

Six patients (c 7 per cent) of the anticoagulant group and 8 (c 9 per cent) of the controls died during treatment all with either trochanteric fractures or fractures of the femoral neck The causes of death are collected in Table 6 unfortunately not all of them were autopsied (see Table 6)

The average age of the dead patients was over 82 Most of them were already in poor condition on admission Ten of these 14 patients sustained the fracture in their own room falling on the floor 1 fell out of bed in a home for the aged 1 fell down in the X ray department of the hospital 1 on the stairs at home and 1 on the street

The patients were followed up for 13–18 months after discharge The results of fracture treatment were about the same in the two groups Pseudarthrosis developed in about 4 per cent of the diaphyseal fractures of both groups Delayed union was established in two cases of the phenylindandione group only There was nothing to indicate that the ossification disturbance occurring in fractures among the patients given phenylindandione would not have developed if the anticoagulant had not been administered

The series is limited in size and especially the number of the representatives of each sub group small Hence it is impossible to draw conclusions concerning the end results of the fractures In particular comparison of the consolidation times of the two groups requires a large material which is homogeneous ar regards age type of fracture and details of treatment It is impossible in clinical work to establish the consolidation times accurately and the length of the treatment period is also affected by so many even secondary factors that comparison is precluded The answer to many important questions must be left to animal experiments which have been conducted concurrently with this study by *Rokkanen & Slatis* (1963)

DISCUSSION

The duration of phenylindandione prophylaxis varied The period was governed not by the conditions of the investigation but by the clinical requirements and the patient s recovery

Venous thrombosis was successfully prevented by using phenylindandione—in the prophylaxis group there was not a single clinically manifest venous thrombosis whereas nearly 16 per cent of the controls were thus affected The latter figure would surely have been considerably

higher had the earliest and most complete possible activation exercise and ambulation not always been a rule in the hospital (*Kallio* 1960)

Pulmonary embolism was established clinically in only c 1 per cent of the patients receiving anticoagulant therapy but in 8 per cent of the control It was the main cause of death in 3 per cent of the control group as a whole and in over 37 per cent of the fatalities of the group

Other arterial thromboembolisms were established in another 7 patients in the control series alone All these embolisms were very serious complications In only one a case of mesenterial thrombosis was the arterial thromboembolism the direct cause of death

Of the other complications the haemorrhagic complication deserves especial attention The phenylindandione and control groups did not differ as regards the course of the trauma induced wound or fracture haematoma The same is true of operation wounds and even of the cases in which anticoagulant prophylaxis was initiated on the first post-operative day Three of the phenylindandione patients however had melaena or haematuria This was not clinically significant in 2 cases and ceased when the anticoagulant was discontinued It was a secondary cause of death in 1 case It is obvious that although no recognised contraindications can be demonstrated special care must be observed in the administration of phenylindandione to the aged (*Hueber* 1961)

No difference was established between the anticoagulant and the control groups regarding the incidence and severity of decubitus (*Leypold et al* 1961) wound infections and other complications

In the diaphyseal fractures of the phenylindandione group delayed union occurred in c 4 per cent and pseudarthrosis in c 4 per cent Pseudarthrosis was established also in c 4 per cent of the diaphyseal fractures of the controls

Fractures of the cancellous area the proximal part of the femur healed similarly in both groups The fact that there was only one pseudarthrosis following fracture of the femoral neck in both groups is probably *due to the individual non schematic selection of therapeutic me*thods for this fracture

There seemed to be an unusually extensive cloud like callus formation of the sort often seen after intramedullary nailing in 2 conservatively treated cases of femoral fracture in the anticoagulant group One of them resulted in pseudarthrosis the other in union This observation is by no means unique in a fracture material but in these cases may have been due to the anticoagulant administered

CONCLUSIONS

Anticoagulant prophylaxis with phenylindandione seems to be well suited for the prevention of venous thrombosis and hence of pulmonary embolism in middle aged or older patients with lower limb fracture

It has also a distinctly preventing effect on arterial thromboses Hence anticoagulant prophylaxis obviously reduces mortality in patients with a susceptibility for venous or arterial thrombosis

The anticoagulant used may in some cases delay union of diaphyseal fracture

Carefully controlled anticoalugant therapy does not seem to increase the haemorrhagic complications of traumatic and operative wounds

Points to be remembered specially in treating elderly persons in poor physial condition with phenylindandione are mucosal haemorrhages or an enhanced susceptibility to bleeding for unknown reasons

SUMMARY

Eighty nine patients aged 40 or more who had fractures of the femoral neck trochanteric fractures fractures of the femoral diaphysis or of the tibial (and fibular) diaphysis were treated conservatively or operatively In addition they were given phenylindandione prophylactically from the 2nd–5th post traumatic or post operative day until they were discharged or had become satisfactorily mobile An equal number of similar fracture patients were treated concurrently by the same methods but without anticoalugant prophylaxis

No clinically demonstrable case of thrombosis of the peripheral deep veins occurred in the anticoagulant prohylaxis group as compared with 16 per cent in the control series Pulmonary embolism was diagnosed clinically in 1 per cent of the anticoagulant group and in 8 per cent of the control group in the latter it was also the main cause of death in 3 per cent of the group as a whole and 37 per cent of the fatalities in the group In no case was *pulmonary embolism the cause of death in the* prophylaxis group

Other arterial thromboembolisms were established in the control group only (8 per cent) One of them was fatal In the phenylindandione series blood appeared in the urine or faeces of 3 old persons in poor health The bleeding ceased in 2 after the discontinuance of anticoagulant administration but in the third patient haemorrhages from mucous

branes were a contributory factor to death One of the controls showed a similar haemorrhagic complication the cause of which was not established

No other haemorrhagic complications were found

The incidence of other complications was practically the same in both groups

The end results of the fractures were about the same in the two groups Pseudarthrosis developed with equal frequency i e in about 4 per cent of the diaphyseal fractures of both groups Delayed union was seen in two cases of the phenylindandione group only

The impression gained is that anticoagulant prophylaxis with phenylindandione is beneficial for elderly fracture patients immobilised for long periods but caution is necessary in the treatment of old people in poor condition and careful control is even more important than usually

RESUME

89 malades agés de plus de 40 ans avec fracture du col femoral du trochanter de la diaphyse femorale ou tibiale (et fibulaire) ont subi un traitement conservateur ou chirurgical En plus il a été administré aux malades entre les 2eme et 5eme jours qui ont suivi le traumatisme ou l operation de la phenylindandione a titre prophylactique jusqu au jour ou le malade a quitte l hôpital ou est devenu suffisamment mobile Un nombre egal de malades souffrant de fractures similaires ont été traités simultanement par les memes méthodes mais sans prophylaxie anticoagulante

Aucun cas de thrombose des veines profondes periphériques n a éte observe cliniquement dans le groupe traité par prophylaxie anticoagulante alors qu il y en eut 16 % dans les séries de controle L embolie pulmonaire a ete diagnostiquee cliniquement dans 1 % du groupe anticoagulant et dans 8 % du groupe de controle dans ce dernier groupe il a éte la principale cause du deces dans 3 % de l ensemble du groupe et dans 37 % des cas de mortalite du groupe Dans le groupe prophylactique l embolie pulmonaire n a eté dans aucun cas la cause du deces

D autres thromboembolies artérielles ont ete observees mais seulement dans le groupe de controle (8 %) L une d entre elles amena le deces Chez les malades auxquels de la phenylindandione a ete administree on a observe du sang dans l urine et les selles de 3 personnes agees en mauvais etat de sante L hemorragie cessa lorsqu on suspendit

l'administration de l'anticoagulant deux jours de suite mais chez le troisieme malade les hemorrhagies des membranes muqueuses ont ete un facteur contributaire du deces Chez un malade du groupe de controle il y a eu des complications hemorragiques similaires dont la cause n a pas ete etablie

Aucune autre complication hemorragique n a ete observee

L incidence des autres complications a pratiquement ete la meme dans les deux groupes

Le resultat final du traitement de ces fractures a ete a peu pres le meme dans les deux groupes Une pseudarthrose se developpe avec une frequence egale dans environ 4 % des fractures diaphysaires des deux groupes Un retard de soudure a ete constate dans deux cas mais seulement dans le groupe a la phenylindandione

L impression retiree est que la prophylaxie anticoagulante a la phenylindandione est bonne pour les malades ages souffrant de fractures et qui sont immobilises pendant une longue periode mais qu il est necessaire d etre prudent lorsque le malade age est en mauvais etat de sante et qu un controle minutieux est encore plus important que d ordinaire

ZUSAMMENFASSUNG

Achtundneunzig Patienten im Alter von 40 Jahren oder daruber hin aus die Bruche des Schenkelhalses Trochanterbruche Bruche der Femurdiaphyse oder der Tibia (und Fibula) diaphyse hatten wurden konservativ oder operativ behandelt Ausserdem bekamen sie Phenyl indandion prophylaktisch vom 2–5 postoperativen oder posttraumati schen Tag bis sie entlassen wurden oder zufriedenstellend beweglich waren Eine gleiche Anzahl von Patienten mit ähnlichen Brüchen wurde ubereinstimmend mit gleichen Methoden aber ohne antikoagu lierender Prophylaxe behandelt

Kein klinisch nachweisbarer Fall von Thrombose der peripheren tiefen Venen entstand in der Gruppe mit Antikoagulationsprophylaxe wahrend 16 % in der Kontrolreihe auftraten Lungenembolie wurde klinisch in 1 % der Antikoagulationsgruppe und in 8 % der Kontrol gruppe diagnostiziert In der letzteren Gruppe war sie auch die Haupt ursache des Todes in 3 % der Gesamtgruppe und in 37 % der Todesursachen in der Gruppe In keinem Falle war sie die Todesursache in der prophylaktischen Gruppe

Andere Thrombo-embolismen entstanden nur in der Kontrolgruppe

(8 %). Einer davon war letal. In der Phenylindandiongruppe wurde bei 3 alten und schwächlichen Personen Blut im Urin oder den Faeces beobachtet. Die Blutung hörte bei zweien nach der Unterbrechung der Antikoagulantverabreichung auf, aber bei der dritten Patienten waren Schleimhautblutungen ein Faktor, der zum Tode beitrug. Einer der Kontrolpatienten zeigte eine ähnliche Blutungskomplikation, deren Ursache nicht ermittelt werden konnte.

Keinerlei andere Blutungskomplikationen wurden gefunden.

Das Vorkommen anderer Komplikationen war das Gleiche in beiden Gruppen.

Die Endergebnisse hinsichtlich der Bruche waren ungefähr die gleichen in beiden Gruppen. Pseudarthrosen entwickelten sich mit gleicher Haufigkeit, d. h. in ungefähr 4 % der Diaphysenbruche bei der Gruppen. Verzogerte Heilung wurde in zwei Fällen der Phenylindandion gruppe allein geschehen.

Man erhält den Eindruck, dass antikoagulierende Prophylaxe mit Phenylindandion bei alteren Patienten mit Brüchen, die für eine längere Zeit ruhiggestellt werden, günstig wirkt. Vorsicht ist jedoch nötig bei der Behandlung von alten Menschen, die sich in schlechtem Zustand befinden und eine genaue Überwachung ist hier besonders notwendig.

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FROM THE DEPARTMENT OF PHYSICAL MEDICINE, RIGSHOSPITALET, UNIVERSITY HOSPITAL, COPENHAGEN (HEAD: OVE BOJE, M.D.)

ULTRASONIC TREATMENT OF CICATRICALGIA

By

OLE MUNE and KJELD THORSETH

After operations various kinds of pain frequently occur. In some of the cases the cause of the pain is for instance peptic ulcer, dumping, ventral hernia or biliary dyskinesia, but often the cause is unknown (*Dahl Iversen et al.* 1958). In a number of cases the pain can radiate from the cicatrice which feels sore and infiltrated (cicatricalgia).

In certain cases local anesthetics can be used to test the localization of the pain, and repeated injections have been used as treatment.

Short wave and massage have but slight effect, whereas relaxing exercises and respiratory exercises appear to be effective in some cases (*Winther* 1958).

Thoracolumbar sympathectomy has been performed with good primary result in some cases (*Bisgaard Frantzen* 1949).

Till now only few descriptions have been given of ultrasonic (u.s.) treatment of cicatricalgia. Pohlman, who has used u.s. for the treatment of 8 patients suffering from cicatricalgia, obtains complete remission of pain in all of them, and *Aldes* (1956–1957) obtains remission in 21 out of 28 patients. *Rubin & Kuitert* (1955) find good effect by u.s. treatment of scars and phantom pains.

By electronic microscopy of u.s. treated cicatricial tissue *Bierman* (1954) has shown changes in its fibrils and interfibrillar substance but no pathological effects in the surrounding tissue.

As regards the u.s. effect and the technique employed reference is given to the preceding article.

OWN INVESTIGATION

The material covers a period of three years comprising patients referred from various surgical departments of the Rigshospitalet, Copenhagen.

The material (see Table 1) comprises 45 patients, 27 women and 18 men. The average age is 46 years.

The average number of u.s. sessions per patient has been 8. Of these patients 22 showed complete relief of pain, 15 patients showed improvement, and in 6 patients the condition remained unchanged, whereas the pains were intensified in 2 patients.

If the patients are left out of consideration in whom no soreness or changes in the consistency were found in or round the cicatrice prior to u.s. treatment, and who have been treated ut aliquid fiat, the number of patients is reduced to 38, of whom 35 improved or were cured.

The two patients whose symptoms worsened had no soreness in the cicatrice.

No side effects have been seen.

DISCUSSION AND CONCLUSION

The patients' pain may have had different origins. It can have been profound visceral pains (colics) or pains projected to the skin via axon reflexes (viscerocutaneous reflexes).

Moreover, the pains can be due to changes in and round the cicatrice manifesting themselves as soreness and change of the consistency by palpation and pain by passive distension of the cicatrice and active contraction of the surrounding muscles.

38 of our 45 patients have had these sore changes of consistency in and round the cicatrice, and in 92 per cent of the cases these changes decrease or disappear after the u.s. treatment.

Of 7 patients who only had deep pains and no cicatricial soreness there was only effect in one.

These circumstances seem to indicate that the u.s. effect is due to affection of the cicatricial tissue and not of the reflex arch or viscera.

Six of the patients had received earlier treatment for the cicatricial pains in the form of a series of blockades of local anesthetics. Each time the effect only lasted a few hours, however.

It is important to treat sore cicatrices as the pains appear especially by activation of the patients, and as they can thus impede or delay their rehabilitation. Pains in thoracal cicatrices, for instance, will impair the respiration and the mobilization of columna thoracalis which may among other things result in scolioses.

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abscessus pulm		1		49	11			1		
cancer pulm		1		50	[illegible]				1	
			1	64	12			1		
			1	65	6			1		
trauma thoracis		1		40	6				1	
Σ	5	3	2	53	8		–	3	2	
Laparotomia med. inf										
amputatio uteri			1	40	12			1		+ profund pain
			1	42	12				1	
parametritis			1	36	9			–	1	
amputatio uteri			1	40	10			1	–	no primary soreness of cicatrice
Σ	4		4	40	8			2	2	
Nephrectomia										
nefrolithiasis			1	33	10			1	–	+ diffuse soreness
		1		49	[illegible]			–	1	
		1		62	12			–	1	
		1		40	10			1		no primary soreness of cicatrice
Σ	4	3	1	46	8			[illegible]	2	
Others										
sympathectomia			1	[illegible]	6				1	
[illegible]tomia colli femoris			1	38	8		1			no primary soreness of cicatrice
[illegible]tomia humeri		1		[illegible]	10		1			
amputatio fem		1		[illegible]	10				1	
incisio (furunculus)		1		29	10				1	
vulvectomia (cancer)			1	[illegible]	[illegible]				1	
appendectomia			1	30	[illegible]			1	–	+ fibrositis in abdominal muscles
amputatio mammae			1	53	6			–	1	
				54	10			–	1	
torticollis		1		43	6			1		operated on 16 years old
total	45	18	27	46	8.6	2	6	15	22	

SUMMARY

45 patients are treated with ultrasound for cicatricalgia. In 38 of the patients objective changes were found in the cicatrices prior to the treatment and in 35 of these patients improvement or complete remission of symptoms was found. Of the remaining 7 patients who had no soreness or changes of consistency in the cicatrices only one indicated improvement.

RÉSUMÉ

45 malades ont été traités par ultrason pour algies cicatricielles. Chez 38 des malades on avait trouvé des changements objectifs des cicatrices avant le traitement et chez 35 de ces malades on obtint une amélioration ou la suppression complète des symptomes. En ce qui concerne les 7 autres malades chez lesquels il n'y avait pas de sensibilité ou de changement de la consistance de la cicatrice une amélioration n'a été constatée que dans un seul cas.

ZUSAMMENFASSUNG

45 Patienten wurden mit Ultraschall wegen Narbenschmerzen behandelt. Bei 38 der Patienten wurden objektive Narbenveränderungen vor der Behandlung gefunden, und bei 35 von ihnen erhielt man eine Besserung oder ein vollständiges Verschwinden der Symptome. Von den übrigen 7 Patienten, die weder Empfindlichkeit noch Konsistenzveränderungen in den Narben zeigten, gab nur einer Besserung an.

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FROM THE DEPARTMENT OF PHYSICAL MEDICINE RIGSHOSPITALET
UNIVERSITY HOSPITAL COPENHAGEN (HEAD OVE BOJE M.D.)

ULTRASONIC TREATMENT OF SUBCUTANEOUS INFILTRATIONS AFTER INJECTIONS

By

OLE MUNE and KJELD THORSETH

Repeated subcutaneous injections of different medicaments for instance antibiotics insulin and iron preparations often bring about traumatism of the subcutis with changes in the tissue These infiltrations are painful sore and feel like granulations of harder consistency than that of the surrounding subcutis occasionally they can also be found in the muscles

As it is not generally known that ultrasonic (u s) treatment is a very effective treatment of these changes and as we have not been able to find any description of it in literature we feel justified publishing this material

Ultrasound was introduced in medicine in 1938 by the physicist *Pohlman*

U s waves are mechanical oscillations produced by making a quartz sheet coupled to an alternating current supply vibrate The frequencies employed in the therapy now are about 1 000 kHz

The wavelength is 1 5 mm The waves spread in a line from the quartz sheet fixed to the soundhead and are quickly braked in the air and by surfaces The mechanical energy is thus transformed into thermal energy In adipose tissue the depth of penetration is 10 cm During the particle movements alternating areas of concentration and rarefaction may be produced in the substrate (cavitation) Reference is given to the following publications *Pohlman* 1951 *Craudal* 1957 and *Licht* 1958

Own investigations

The aim has been to examine the effect of u s treatment of infiltrations caused by injections

Technique

The ultrasonic apparatus employed was a Siemens Sonostat 631. Intensities used ranged between 0.5 to 0.8 watt/cm² and frequency 870 kHz. The size of the soundhead 1.3 and 4 cm², depending on size of area to be treated. Duration of treatment was about 5 minutes. The skin of the area to be treated is smeared with a thin coating of paraffin oil and the soundhead applied in a slow movement over the diseased area. The patient feels no pain but possibly a slight sensation of heat during the treatment.

MATERIAL

15 patients with subcutaneous infiltrations have been treated during the past two years.

The age of patients ranged from 23 years to 66. 13 women and 2 men. In 11 cases the cause of the infiltrations was repeated injections of Na penicillin, in some cases combined with streptomycin. 3 of the patients had had insulin, 1 Imferon and 1 pethidin. The duration of the symptoms was from one month to some years.

In 8 of the patients the infiltrations were localized to the gluteal regions and in 7 to the femora.

The u.s. treatment was given in series of 6, either daily or every other day. 4 patients had 6 sessions, 11 received 10 or 12 sessions. The pain and soreness disappeared in all the patients. The objective changes decreased considerably in 10 patients and disappeared completely in the remaining 5.

In no cases was damage to skin, muscle or bone seen and the treatment gave no kind of discomfort.

CONCLUSION

Our material shows that u.s. is an effective and painless treatment of infiltrations caused by injections.

SUMMARY

The material covers 15 patients with infiltrations caused by injections in subcutis, treated effectively with u.s. The treatment is painless and without side effects.

RÉSUMÉ

Le matériel d observation comporte 15 malades souffrant d infiltrations causées par des injections sous cutanées traitées efficacement par ultrason Le traitement est sans douleur et sans effets secondaires

ZUSAMMENFASSUNG

Das Material umfasst 15 Patienten mit durch subkutanen Injektionen hervorgerufenen Infiltraten die wirkungsvoll mit Ultraschall behandelt wurden Die Behandlung ist schmerzlos und ohne Beiwirkungen

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PROCEEDINGS OF
THE NORDISK ORTOPEDISK FORENINGS 31ST ASSEMBLY
AND
THE BRITISH ORTHOPAEDIC ASSOCIATION'S
AUTUMN MEETING IN COPENHAGEN

AUGUST 27–30, 1962

The meeting of the 31st Meeting of the Scandinavian Orthopaedic Association was held under the precidency of A. Monberg, chief surgeon, Dept. III, Orthopaedic Hospital, Copenhagen.

ABSTRACT OF THE PRESIDENT'S OPENING ADDRESS

First, I want to bid you all cordially welcome to the 31st meeting of the Scandinavian Orthopaedic Association and thank you for doing me the honour of electing me president of this meeting.

This congress is rather different from earlier ones, as the British Orthopaedic Association has asked us whether they could hold a joint meeting with us here in Copenhagen. To us it has been a pleasure to comply with this request, which we consider a great honour.

Since I shall now soon be retiring from my orthopaedic life and resigning my duties in various organization, and since I have attended most of the meetings held since our Association was founded, it may be of interest, not least to the younger generation, to hear about the men who founded this Association.

From the beginning of this century orthopaedic speciality in Scandinavia was in the hands of a few people who were, I might say, autodidacts. The authorities afforded very little help to crippled and disabled persons, and bandages, corsets and splints were delivered from only a few makers of surgical appliances with very little expert knowledge. Iron supports were generally made by the local blacksmith. In fairness I must say that I have seen a number of these appliances which proved satisfactory, but on the whole the development was in a primitive stage.

In this country, as early as 1872, a retired clergyman, *Hans Knudsen*, had founded the Society "which take care of crippled and maimed children", the later Society and Home for Cripples. The great idea which inspired him was to build up a close collaboration between the surgical treatment, training and education of the unfortunate patients who were unable to take part in everyday life and unable to earn their living because of congenital or acquired disablement. But as it was difficult to procure the means needed to carry out these plans, there was a limit to the help which could be rendered.

The Society and Home for Cripples has always been and still is a private institu-

tion but with a considerable Government subsidy so that the solution of this constructive work has now become a Government concern

The surgical work was carried out free by interested surgeons (*Barf, Sigfred Levy, Ipsen* and *Drachmann*) until in 1908 Dr *Fanum* became surgeon in chief. In 1919 he was succeeded by *Guildal* who was up to 1950 the guiding spirit of the great development which took place during this period. Guildal was also lecturer in orthopaedics to the University of Copenhagen where a professorship was not founded until 1957. A second professorship was founded in Aarhus in 1955.

In Stockholm *Patrik Haglund* became professor of orthopaedics in 1913. There have been great advances in the development of orthopaedics and the care of cripples in Sweden which now has 4 homes for cripples, 5 professorships, and in the central hospitals throughout the country 30 orthopaedic departments.

In Norway a home for cripples, Sophie's Minde, was founded in 1902. This was an extension of the school for crippled children run by the *Fleischer* sisters in Oslo since 1892. It is still owned by a foundation but it is run by the Government. It is a combination of a training school, orthopaedic department, and workshops.

In Finland the credit for organizing and centralizing the treatment and training of civilian and war cripples is *Fabian Langenskiold*'s. As in the other Scandinavian countries there were scattered training schools for the disabled which gradually were being extended by the large number of war cripples resulting from the belligerent dealings with the neighbour. However it was not until 1940 that the Disablement Foundation was established in order to centralize the treatment and training of invalids and cripples, whereby this became a Government concern.

In 1926 an event took place in Trondheim which was of the utmost importance. At a joint meeting of the various sections engaged in the care of handicapped persons—the blind, the insane, the deaf, and the crippled—the representatives of the cripples segregated and formed a Scandinavian association which was called the Scandinavian Association for Cripples (Nordisk Vanforeforening). This proved of inestimable importance as it collected the scattered training schools for cripples and attached to them orthopaedic departments.

But prior to this meeting the development had been discussed by interested surgeons, the Scandinavian Orthopaedic Association being founded by *Bülow Hansen* of Norway, *Patrik Haglund* of Sweden, and *Slomann* of Denmark.

Let me now try to give you an impression of these three leading personalities from the early years.

Bülow Hansen, senior surgeon of Sophie's Minde, Oslo, until 1931, was the primitive but nevertheless realistic in the method of treatment which he used in order to obtain the best possible result under the prevailing conditions. However difficulties abounded among others the long distances to Oslo, the limited means of communication, and the impossibility of defraying the considerable travelling expenses. Bülow Hansen therefore soon started using bone stabilizing operations in order to avoid the use of bandages which often needed repair and renewal. It may be mentioned that in the treatment of congenital clubfoot the method was wedge resection even at a very early age. His reasoning was that it was most important for the child to be supplied with a sole to walk on, a foot which would not need after-treatment and follow up. We who can remember him shall never forget his gestures when he gave his lectures, his youthful face with the martial looking moustache. He was a characteristic artistic personality of a cheerful disposition.

The second founder was *Patrik Haglund* professor of orthopaedics in Stockholm from 1913 to 1937 a magnificent figure of a man taking an idealistic attitude to the work which he undertook He has left an enormous number of publications—about 300—on subjects within orthopaedics and the care of cripples but also on subjects such as physics and astronomy *Haglund* was a scholar of German orthopaedics Let me mention his bulky publication "Die Prinzipien der Ortopadie (1923) and his numerous papers on the treatment of the sequelae of poliomyelitis His papers often contained philosophical reflections and his descriptions were characterized by great thoroughness and meticulous care *Haglund* was the founder of Acta Orthopaedica Scandinavica and on the whole embodied the spirit of scientific development in Scandinavian orthopaedics We remember his peculiar way of reading a paper He walked to and fro on the platform and if there was a side door or corridor he would go out talking and come back still talking so it was not always equally easy to follow him His contributions to the discussions were always well founded usually marked by strong points of view but suddenly you might hear his youthful laughter which bore witness of his affection for everything and everyone to whom he felt attached A great figure within Scandinavian orthopaedics and care of cripples

The third founder was *Herman Slomann* a very intelligent man but of a somewhat depressive disposition It was typical of him that after having started his hospital career in Vejle Jutland he found that this sort of work seeing patients at all times of the day and night was too much for his temperament He wanted time to make therapeutic plans Owing to this forced work he went to Copenhagen in 1901 and established an orthopaedic clinic with 20 beds This clinic was highly esteemed not only in Denmark but throughout Scandinavia The fact that four doctorate theses were written in this clinic bears witness to his inspiring scientific talents Dail

llaboration with *Slomann* was enriching his examination and treatment planning being very thorough His reflections regarding possible complications often bore the marks of his rather depressive disposition

I want to mention also *Guildal*'s contribution to the congresses This handsome and stately man had linguistic ability friendliness charm and a gift for sober evaluation—evident both in lectures and discussions—which made him popular everywhere Like the founders of the Association *Guildal* was made honorary member

Brief mention must be made also of *Sv Johansson* chief surgeon to Sahlgrenska Sjukhuset Gothenburg *Sv Johansson* was the first secretary general of our Association He achieved great things in the treatment of fracture of the neck of the femur

And let me mention also our present Scandinavian honorary members *Henning Waldenstrom* and *P G K Bentzon* *Waldenstrom* succeeded *Haglund* as professor of orthopaedics in Karolinska Institutet Stockholm *Bentzon* was secretary general editor of the Acta Orthopaedica Scandinavica and on the whole took such a great interest in the welfare of the Scandinavian Orthopaedic Association

This brings me to my own generation or rather the next of which we have such a distinguished representation to-day We are looking forward to hearing in the next few days your papers and discussions which will no doubt afford a vivid picture of present day orthopaedic

TRAITS IN AMPUTATION SURGERY AMONG CIVILIANS DURING THE PERIOD 1930–1960

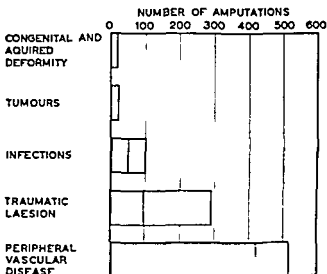
by *Ralf Lindholm* (Helsingfors)

Mainly with a view to detecting changes in composition of series, amputation characteristics and philosophy, the author has made a survey of the case records on nearly one thousand clinical amputations. The operations were performed at the surgical department of the Maria City Hospital, Helsinki-Helsingfors, a unit dealing with patients in need of emergency as well as planned surgery. The area served by this hospital is the capital city, with somewhat under half a million inhabitants by the end of the period surveyed.

Interest has been focused upon questions of operative indications, age and sex frequency and level of surgery, primary operative risk and evaluation of trends revealed in these in the course of time.

Of all amputees, 2/3rds were men. More than 50 per cent were aged between 50 and 80 years at the time of surgery. The rate of amputations in relation to all surgery done makes 6 to 20 per thousand, the latter number being indicative of the figures of later years. The annual frequency of amputation for peripheral vascular disease has been estimated at about one amputation per ten thousand inhabitants.

TABLE 1

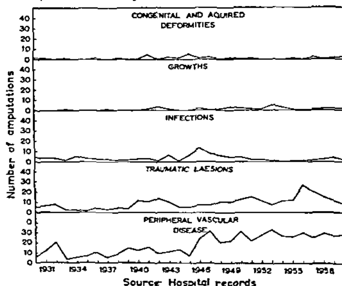


Source: Hospital records

MINOR AMPUTATIONS 

MAJOR AMPUTATIONS 

TABLE 2



Only 12 per cent of the limbs subjected to amputati on have been upper extremities while the majority or 78 per cent have been lower extremities. In terms of risk of death in the postoperative period of hospital stay the figures appear to indicate the importance of underlying disease as a cause of failure rather than operative trauma and stress

A study of chronologic sequence has revealed a significant rise in the mean age of persons undergoing amputation for vascular disease and infection and an actual as well as relative increa e in the number of operations f r vascular dis rders and traumatic lesions

(To be published later in more detail in the Acta Orthopaedica Scandinavica)

KITON FAST GREEN AS AN AID TO THE DIAGNOSIS OF TRAUMATIC SOFT TISSUE INJURIES TO THE ARMS AND LEGS

by Arne Kj llgren (G thenburg Sweden)

Judging the vitality of laceration injuries and deep sec nd degree burns n the extremities offers n t infrequently considerable diagnostic difficulty even f r the m t experienced urgeons Variou meth ds have been initiated to btain an bjective meth d of in estigation In fact only the sensitivity test in burns has proved of value in clinical practice but it is beset by fundamental weaknesses The m thod publi hed by Tempe t in 19 9 of vital c l uring with kit n fast green er di ulfine blue eems t pro ide a valuable contributi n f the diagn si The c l ur substance is inj cte l intraven u ly Vital tissues i.e., those with sufficient blood

supply are coloured intensive green or blue while those with serious circulation disturbances are coloured weakly and unevenly or not at all. The colour medium has no side effects. Some typical cases are reported.

DISCUSSION

Håkan Brattström (Lund, Sweden)

At the Orthopaedic Clinic in Lund we have tried to use the medium in order to obtain a guide for determining the amputation level in senile gangrene. Our experience is still small but our impression is that the medium, the use of which is based on skin circulation, easily gives a too favourable picture. The deep circulation is worse in these patients than the beautiful green colouring may give the surgeon cause to believe. Therefore the examination must be critically evaluated so that an amputation is not performed too far distally.

Arne Kjellgren

Vital colouring with lithon fast green was carried out in some cases of diabetic gangrene. My preliminary conclusion is that the method has not provided any important aid in determining the amputation level.

OSTEOCHONDRITIS DISSECANS GENU

by *Lars Mårtenson* and *Sten Scheller* (Gothenburg, Sweden)

SIDE DIFFERENCE IN SIZE OF OSSIFICATION CENTRES AND IN BONE LENGTH IN JUVENILE GONARTHRITIS

by *Merete Brattström* (Lund, Sweden)

About 50% of juvenile rheumatoid arthritis starts as an isolated gonarthritis. After months or years a progression with engagement of other joints makes the diagnosis possible.

By conventional judgement of X-ray pictures of knees from these patients rather insignificant changes such as slight osteoporosis and lowering of cartilage are usually found. It is easy to underestimate the pathological process, which if it remains untreated may have serious consequences for the future function of the knee (persistent contracture, subluxation, valgity).

Here an attempt is made to measure the X-ray changes in 12 cases of unilateral or asymmetrical gonarthritis collected at the Rheumatic Clinic, Lund (Children Department).

The treatment of the patients was uniform: bed rest, stretch and physical training interrupted by 1–2 week periods of plaster till full correction of flexion contracture was obtained. Medicine: Salicylics. Mean time at hospital was 6.8 months. X-ray controls were made regularly comprising frontal and side exposures (knee stretched, semiflexed respectively) and longimetry by the orthodiagraphic method.

The relative size of the femoral condyle was calculated by measuring epiphyseal breadth and average hight of medical and lateral condyle on the frontal picture

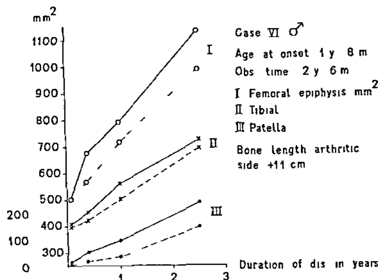


Fig 1

A typical case with 2 5 years duration of arthritis Bilateral symmetry is seen at time of onset The side difference is significant on X ray picture taken after 4 months

+100
+90
+80
+70
+60
+50
+40
+30
+20
+10

Case	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Age at onset (months)	15	17	18	19	20	20	24	27	29	31	33	33
Obs time	30(9)	28	120	34	7	30	70	9	30	38	17	31

Side diff in % arthritic–sound side (12 cases)

1 ▨ Patella 2 ☐ Femoral epifysis 3 ■ Bone length

Fig 2

The side difference in ossification (% of healthy side) at the end of observation time

The patella was measured on the side picture maximal length and breadth at right angles Bone length was defined as total osseous part of femur and tibia measured separately

In this material an overgrowth of femoral epiphysis of 5–40 % and of patella of more than 40 % was regularly found together with an elongation of the arthritic leg of 0 5–2 5 cm

TWO CASES OF ABNORMAL SKELETAL GROWTH FOLLOWING TRAUMA

by *Poul Lütken* (Aalborg Denmark)

With reference to a report on skeletal growth at the Helsinki meeting in 1956 an example was demonstrated of conversion of skeletal curves having a small radius to curves having a larger radius pronounced bone growth in the concavity and absorption from the convex aspect

X ray films were presented of a child aged 9 years with a history of aseptic osteomyelitis following intraosteal blood transfusion at the age of 6 weeks A large necrosis appeared proximally in the diaphyseal centre of ossification on the right tibia

Although the necrosis involved the central parts of the growth zone longitudinal growth as well as growth in thickness continued The films show that ossification took place from the proximal epiphyseal centre replacing the missing diaphyseal ossification in the destroyed area Thereby the non ossified growth zone acquired an abnormal situation (cf the sketch)



(a) Abnormal situation of epiphyseal line in the anterior half of the proximal tibial end

(b) Normal appearance

The boy has been followed up for 9 years and growth continues The site of the epiphyseal line was shown on tomographic cuts

A similar replacement of epiphyseal ossification in an area which normally ossifies from the diaphyseal centre may be encountered as a normal variant at the upper ridge of the neck of the femur described by me at the meeting in Oslo in 1960 This variant is popularly known as an elephant hip

Finally the radiographic appearances of total epiphysiolysis of the distal femoral epiphysis in a 10 year old boy In the local hospital he had been treated primarily by absolute anatomical reduction

Five years later I saw the boy Owing to total inhibition of growth at the dorsal edge of the epiphysis and continued growth at the anterior aspect of the femur the

epiphysis had rotated almost 90 in the direction of flexion. There was only a negligible extensor defect in the knee and a shortening of 2 cm. The therapeutic pr blems were briefly discussed.

(A somewhat extended and modified communication is being prepared for publication in Acta Orthopaedica.)

EXCITATORY AND INHIBITORY REFLEX MOTOR EFFECTS FROM THE PARTIALLY RUPTURED MEDIAL COLLATERAL LIGAMENT OF THE KNEE JOINT

by *B Stener* and *I Petersen* (Gothenburg, Sweden)

A large increase in tension can be brought about in the *un njured medial collateral ligament of the knee joint in man without the elicitation of activity in sartorius* semimembranosus or vastus medialis, i e muscles capable of actively supp rting the ligament s lateral stabilization of the joint (*Petersen & Stener* 1959) With the ligament *injured* qu te different results are obtained the present paper provides an account of this phenomenon

Thirty patients with partial rupture of the medial collateral ligament of the knee joint (stability intact) were studied, using electromyography to determine the effect on the musculature of the thigh of an increase in the tension in the ligament Mainly this increase in tension was brought about by abduction at the joint and by pas ive extension beyond what the patient could achieve (the majority of patients had impaired active extension)

In all the patients activity was evoked in sartorius in resp nse to the increase in the ligament s tensi n and in mo t of them in semimembranosus as well On the other hand activity was only exceptionally evoked in vastus medialis instead an inhibitory effect on the activit in this muscle was bserved if abducti n was performed while the patient voluntarily contracted quadriceps

Pressure at the site of the rupture led to the same results as an increa e in ten ion in the injured ligament Pressure and an increase in tension both ev ked pain at the site of the rupture Se eral factors discussed in detail indicate that the effect lemonstrated was reflexly induced and issued from the ligament itself an l hence can be de cribed as a ligamento-muscular reflex This reflex fr m the *injured* ligament pr bably does n t riginate in tension recept rs but in *pain* recept rs

As far as therapy in a case of partial rupture of the medial c llateral ligament f the knee joint is concerned it has l ng been rec gnized how imp rtant it is that the patient overcomes the impaired extension at the joint by active u e of quadri ep The pre ent study c nfirms the need for such training of quadriceps the ligament muscular reflex from the injured ligament i n t so rganized that this muscle will be trained automaticall

(A detailed account of this investigati n will be published in Acta Chirurgica Scandina ica)

MENTALITY AND DYSTROPHY

by *H Ehl rs* and *L Za har a* (Copenhagen)

"D trophy"—or b tter "po ttraumatic dy tr phy"—is taken f m an the tate which may arise f ll wing injuries f r surgery on a limb an l whi h is characterized b oedema f l r i an l tiffne s a well as vari u v g tative li turl anc s

It is a serious complication which may entail permanent sequelae but despite numerous investigations its exact cause and pathogenesis remain unelucidated and constant matters of discussion

It was the object of the present study to try to elucidate whether the mental state does exert influence upon the occurrence of the dystrophic syndrome

Preoperatively all the patients were seen by the psychiatrist who assesed their character and gave a statement containing a presumption regarding the postoperative course The surgeon was not cognizant of the contents of this statement and all the patients were subjected to the same surgical procedure and after treatment A few months later the postoperative course presumed by the psychiatrist was then compared with the real course So far this study includes 33 male patients operated for Dupuytren s contracture

As already mentioned the material comprises 33 males From the table it will be seen that 30 out of 33 had a postoperative course in conformity with that expected by the psychiatrist

Psychiatric assessment	No of cases	Presumed postoperative course	Actual postoperative course conformable	Actual postoperative course not conformable
Normal	5	Uncomplicated	5	
Unstable	14	Uncomplicated	14	
Demented and arteriosclerotic	5	Uncomplicated	5	
Aggression inhibited Defeatist attitude Self pitying Perfectionistic Non sthenic	5	Short lasting difficulties in restitution	3	2
Aggression inhibited Martyr type Self pitying Agressive Self opinionated Ambitious Hysterical Sthenic	4	Long lasting severe complications	3	1
Total number	*33*		30	3

On the basis of the present studies it may be concluded that an interested psychiatrist who has familiarized himself with these special problems can foretell with great likelihood whether postoperative complications—in the form of edema fibrosis and stiffness—are going to occur in a candidate for surgery on Dupuytren s contracture This is of great importance both in fixing operative indications and in trying to penetrate the aetiology and pathogenesis of the condition called dystrophy

FRACTURES OF THE UPPER END OF FEMUR IN AN URBAN POPULATION

by *P A Alffram* (Malmo Sweden)

Owing to the continuing changes in the age distribution of the population complaints relating to old age have become more and more dominant One of these complaints is the fracture of the upper end of the femur (medial and trochanteric collum fractures)

During the years 1949–1961 1 635 cases of such fractures were diagnosed amongst the 210 000 inhabitants of the city of Malmo Amongst women who formed 75 % of the patients medial fractures were about twice as common as trochanteric fractures Amongst men on the other hand both fracture types were almost equally common The average age of the whole series was 71 8 years 4 years more for women than men and 2½ years more for trochanteric than medial fractures

87 % of the female patients and 52 % of the males had incurred their fractures as *a result of moderate force i e falls to the ground etc while 3 % of the women and* 29 % of the men incurred their fractures through traffic accidents of varying types

The fracture incidence on every 5 year group showed a considerable greater increase with increasing age and a calculation reveal plainly that about 10 % of all women and 5 % of all men attaining 80 years of age have had fractures of the upper end of femur

A comparison of the incidence of female fracture cases in Malmo and Dundee Scotland (*Stewart* 1958) showed a significantly higher incidence in Malmo A corresponding comparison between the conditions in Malmo and Gothenburg (*Mårtensson* 1962) showed on the other hand no difference in the fracture incidence

During the investigation period the number of fracture cases diagnosed annually was tripled while the population increased by 20 % Statistical analysis showed that during this period a real increase in incidence occurred beyond that expected owing to change in the age and sex distribution This increase was mainly to be attributed to the trochanteric fractures There was no corresponding increase in the incidence of severe force or of diseases especially favourable to fractures amongst the patients (hemiplegia poliomyelitis with paresis polyarthritis radiological treatment of the small pelvis etc)

The investigation shows the important difference which exists between the sexes regarding disposition towards fracture of the upper end of femur and also gives an indication of the existence of geographical difference in the incidence of such fracture

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OPERATIVE TREATMENT OF RECIDIVAL DISLOCATION OF THE SHOULDER JOINT

by *Stig Walter* (Linköping Sweden)

(To be published later in the Acta Orthopaedica Scandinavica)

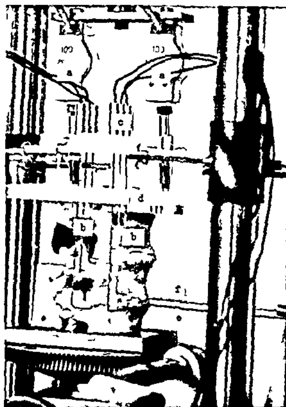


Fig 1

TECHNICAL PROBLEMS IN LUMBAR FUSIONS

by *Stante Rolander* (Gothenburg Sweden)

Chronic low back pain is a disease of vast medical and social importance and a central orthopaedic problem Clinical experience shows that in a great many cases it is possible to eliminate the pain by spinal fusions But in spite of 50 years experience of fusions the opinions of the indications and results are very much divergent

In this situation the author has found it an urgent necessity to try to throw light on the mechanical efficiency of lumbar fusions by means of experimental work

In fresh autopsy specimens it is possible to simulate healed fusions of different kinds by fixing the vertebras in plastic glues the strength of which exceeds that of bone In a compression testing machine the specimens are loaded during simultaneous measurement of the intradiscal pressure The values are compared with those obtained after the fusion is removed It is obvious then that the segmental motion is not prevented and the disc is definitely not unloaded by the fusion Only when the load is applied between the axis of motion and the fusion mass—viz in a dorsal fusion with the specimen in dorsiflexion— is the intradiscal pressure appreciably decreased This means that even if the fusion is sufficiently strong the pedicles specially the intra articular portions are too flexible to withstand the load The same

thing is easily demonstrated if the disc is excised Then the anterior borders of the vertebral bodies are bent together by a load of less than 50 pounds but if the gap produced by excising the disc is big enough the intra articular portions fracture

If a solid fusion has the ability to eliminate pain caused by the disc the reason could not be a total elimination of motion It is however obvious that the pattern of motion is definitely changed by the fusion In order to investigate this change and to obtain more exact knowledge of the physiological and pathological pattern of lumbar movements the author constructed the device the essentials of which are shown in the figure (Fig 1)

The specimen is fixed in a compression apparatus where the load can be applied at different angles It is assumed that the axis of motion passes through the nucleus Thus the loading force (a) as well as the movements (b) are measured on both sides of the axis and simultaneously recorded electronically (a c) It is possible to load the specimen so that the resultant of the applied forces crosses the axis of motion At this moment the disc is vertically loaded which is indicated by a uniform compression of the disc and by a minimal intradiscal pressure (*e*) The compression bar (d) permits movements of the disc in the horizontal plane which are recorded by the gauge (f) placed against the anterior border of the vertebral body

CONGENITAL SYNOSTOSIS IN THE CERVICAL SPINE

by *Poul A* and *Lone Gjorup* (Copenhagen)

The material comprises 76 cases and it is estimated that the syndrome is found in 0 ? per thousand in the population of Copenhagen The synostosis is most frequently found in the upper part of the spine in 13 cases the cervical spine is completely synostosed Other vertebral deformities in the whole spine are found in about 50 coliosi in 71 % Sprengel s deformity in 16 % of the cases

(To be published later in a more detailed form in the Acta Orthopaedica Scandinavica)

EOSINOPHILIC GRANULOMA

by Adre Nyholm (Copenhagen)

In order to get an impression of the course and prognosis of disease the history of 14 children has been reviewed 6 were diagnosed as solitary 8 as multiple granuloma The primary admissions were to different specialized departments as a result of different complaints from varying localization The diagnosis was made by histological examination in all but one case This security in histopathological diagnosis is explained by the early phase of disease in which the histological features are most typical

The roentgenographic picture of the single focus presented a round oval or irregular rarefaction in bone surrounded by a sharp demarcation line This finding was most prominent in the Calvarium and other flat bones while localization in long bones often resulted in dilatation of corticalis producing bonecysts or breaking through of corticalis followed by some sclerosis and healing.

The treatment has been surgical intervention with excochleation of the pathological tissue or X ray irradiation of single foci with small dosis (Total dosis 7 900 r) 7 patients were operated on for osteolytic defect in theca cranii 4 of these defects

were completely healed and filled with normal bone tissue in 3 of the cases inside a year The surgical treatment was in some of the cases supplemented by postoperative X ray irradiation In 2 cases the defects were primarily repaired by placing a plastic plate in the diseased bone while the last one obtained a similar prosthesis 9 years later because of unchanged defect with periodical headache as complaint

Local X ray irradiation of 26 single foci resulted in 15 with complete healing inside a year while all were healed within a follow up period of 5 years Although the influence of irradiation could be accepted as a cooperating factor in some of the cases no certain conclusion could be drawn from the treatment especially not when 8 other foci showed a completed spontaneous healing inside a year and 1 inside a period of 3 years

In conclusion we find that eosinophilic granulomatous processes localized to the osseous system solitary or multiple are a benign disease which run a course of limited time rather independent of treatment An early histological examination can serve the diagnosis while later it often confuses the diagnostic considerations Operative interference with exochleation of the pathological tissue or X ray treatment with small dosis can probably advance healing but the spontaneous course often complicates a certain impression of effect of treatment

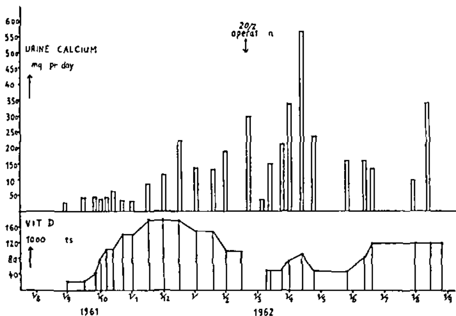
VITAMIN D RESISTANT RICKETS

by *Hans Bohr* (Copenhagen)

Four cases of vit D resistant rickets from the Orthopaedic Hospital of Copenhagen are presented The first two cases are boys born in 1945 and 1958 respectively and



Fig 1



Fig

seen at the age of two years There was no disposition for bone disease in the familie As the rachitic symptoms did not respond to ordinary doses of vit D., they were transferred to the pediatric department of Rigshospitalet and treated with doses of about 100 000 units of vit D gradually reduced to 50 000 units pr day as maintenance dose Normal development has occurred on this treatment and the microradiographic (mrgr) picture of a bone biopsy from the elder boy in 1960 given in Fig 1 shows that the bone structure has become essentially normal

Of the last two cases both women and relatives the younger born in 1947 had correction osteotomies on both femora and the right tibia at the age of 9 The deformity was much improved but recurred at the age of 14 A thorough investigation including mrgr investigation of bone biopsy gave the diagnosis and treatment with high doses of vit D was started Fig 2 shows the increased excretion of calcium in the urine during treatment In Febr 1962 correction osteotomies were performed on both tibiae but mrgr examination showed that the rachitic changes persisted and no uptake of Tetracycline in the bone could be demonstrated The older woman born in 1904 and an aunt to the one mentioned before had correction osteotomies performed on both femora at the age of 19 The deformities recurred and when she was seen in 1961 she had pain in different joints She was treated with 100 000 units of vit D daily and had some relief from her pains A new biopsy 10 months later showed on mrgr examination that normalization of the bone structure had occurred and correspondingly an uptake of Tetracycline could be shown

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JOINT MEETING OF
THE SCANDINAVIAN ORTHOPAEDIC ASSOCIATION
AND
THE BRITISH ORTHOPAEDIC ASSOCIATION

SHOULDER SYMPOSIUM

THE RANGE OF MOVEMENT OF THE SHOULDER JOINT AT VARIOUS AGES

by *L Saario* (Jyvaskyla Finland)

The research material comprises the active range of movement of the shoulder joints in 1280 persons The joints included in the survey were confirmed as healthy by clinical and anamnestic examination They did not reveal pathological symptoms nor did they suffer accidents

It emerged from the investigation that the average range of forward and backward lifting of the upper arm was 240 in the youngest age group i e below 16 while it was 190 in the oldest group (above 70) During aging the range of movement therefore diminshed 50 or approx 21 %

The average abduction range was 166 in young people and 116 in old people The decrease was therefore 50 or 30 %

The corresponding average figures for the rotation movement were 175 and 125 in this instance the range of rotation decreased 50 or 28 %

Raising of the upper arm to the vertical position was successful in only ¼ of all the 16 age groups and after 50 years of age this was only successful in exceptional cases

Complete 180 abduction occurred in the youngest age group in about 40 % After 50 years of age complete 180 abduction occurred only in a few persons

A fundamental factor causing changes in the range of movement in combination with aging is the changed position of the shoulder blade With increasing natural convexity of the spine the shape of the thorax changes and the shoulder blade leans forward at the same time as its position is altered in a sagittal direction This limits both the ability to raise the upper arm forward and also the range of external rotation

FAMILIAR CLINICAL SYNDROMES IN LESIONS OF THE SHOULDER

by *W D Coltart* (London)

Mr W D Coltart (London) referred to the four *outstanding and readily identified* clinical syndromes associated with the scapulo humeral joint which may be designated (1) The Ruptured Supraspinatus (2) Supraspinatus Calcification (3) The

Painful Arc and (4) Frozen Shoulder These syndromes could be referred to as Primary Intrinsic Painful Shoulder because they could be identified by physical signs in the scapulo humeral joint and in that way distinguished from the very large number of extraneous lesions which may cause pain referred to the shoulder – although such things as cervical spondylosis angina pectoris and cerebral hemiplegia may later on produce ankylosis and pain perhaps due simply to immobility The symposium did not need to concern itself with such obvious causes of Painful Shoulder as fracture or tuberculous arthritis

These familiar syndromes were all described by *Codman* over 30 years ago were referred to in a British symposium in 1949 and were well known what was important was to relate them correctly to Morbid Anatomy These shoulders have been explored by Surgeons and three pathological entities have been described (1) Degenerative lesions of the supraspinatus part of the musculo tendinous cuff (2) Calcifying lesions in the tendon and occasionally in the sub deltoid bursa and (3) Complete adherence of the capsule to the head of the humerus

The problem of the Frozen Shoulder would be dealt with by Dr *Magnusson* In the other three syndromes treatment was fairly well standardized The ruptured supraspinatus could be identified by the Procaine test and arthrography as described by the late V *H Ellis* (19 3) but recent discussion amongst experts in the United States suggested that surgical repair was seldom necessary and that immediate repair had no advantage over a delay of 10–14 days In the painful arc hydrocortisone injections had proved of value and acromionectomy was seldom required The surgical removal of the plaque of calcified material in the supraspinatus tendon was a satisfying procedure and easily done provided a correct incision was used Acute attacks of pain from bursting of the calcified material into the sub-deltoid bursa would usually result in a spontaneous cure and rest with heavy *sedation was as effective* as aspiration or deep X ray therapy during the short acute phase

Speculation as to the reason for idiopathic supraspinatus degeneration was *interesting* and was made more so by the observations of *Inman* and his colleagues *on* the comparative anatomy of the shoulder (1944) The facts suggested an increased significance in function of the deltoid and either diminishing or altering *function* of the supraspinatus

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PERIARTHRITIS HUMERO SCAPULARIS

by *Ragnar Magnusson* (Linköping Sweden)

During the years 19[illegible]0–61 272 patients were treated in the Orthopaedic Clinic of the Central Hospital *in Link*öping 115 men and 157 women with periarthritis humero scapularis In [illegible] cases the illness was *present in* both sides The average age for men was somewhat higher than for *women* [illegible] and [illegible] respectively although the difference is not statistically proven

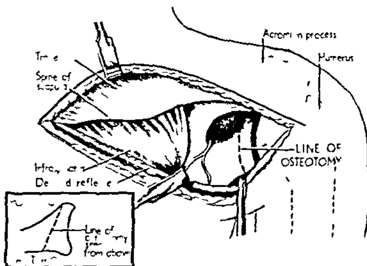


Fig 1



Fig 2

shoulder joint downwards away from the acromion after performing n c teotomy through the neck of the scapula

Operative Technique

With the patient lying prone and the arm in lateral rotation an in i i n is made along the spine of the scapula the deltoid being detached and retracted l wnwards together with the infraspinatus so as to expose the back of the shoulder joint An oblique osteotomy is now performed through the neck of the scapula s as to se

parate the glenoid from the body of the bone A bone spike is now inserted above the upper border of the glenoid which is then levered downwards by counter pressure against the spine of the scapula while downward traction is exerted on the arm

No fixation or splinting is necessary movements being encouraged from a few days after the operation

The operation has proved uniformly successful for those cases where pain is due to friction between the head of the humerus and the acromion and when movements of the shoulder joint are otherwise free

Full function is usually regained within four weeks Pain is relieved so rapidly by this operation that it has been suggested that in addition to its mechanical effect the relief of pain may be analogous to that following a McMurray osteotomy It has also been suggested that it might be helpful when the supraspinatus has been ruptured or paralysed since the downward and medial displacement of the shoulder affords a better leverage for the deltoid

FREE PAPERS

LESIONS OF THE INFRAPATELLAR FAT PAD AND SYNOVIAL FRINGES HOFFA'S DISEASE

by *I S Smillie* (Dundee Scotland)

Internal derangement of the knee joint related to the infrapatellar fat pad exists in two distinct forms

In which the joint is otherwise normal In this variety the fat pad undergoes enlargement from oedema or haemorrhage as a result of a single incident of trauma (Fig 1) or repeated minor incidents Where hypertrophy is of idiopathic origin the condition is frequently bilateral and affecting young females may be of hormonal origin

TABLE 1

Meniscectomies Averages ages (1940–1962)

Years	Case number	Average age
1940–1943	1–500	28
1943–1945	500–1000	29
1945–1951	1000–1500	30
1951–1953	1500–2000	33
1953–1955	2000–2500	34
1955–1957	2500–3000	35
1957–1958	3000–3500	35
1958–1959	3500–4000	36
1959–1961	4000–4500	36
1961–1962	4500–5000	36



Fig 1

Lesions of infrapatellar fat pad etiology In this case the direct injury which produced the scar over the patella was responsible also for hypertrophy of the fat pad

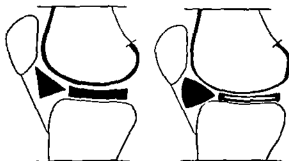


Fig 2

Lesions of *infrapatellar fat pad etiology Diagrams to show effect of degenerative* changes in the meniscus (in the form of horizontal cleavage) together with thinning of articular cartilage on the infrapatellar fat pad of the knee joint the space available is reduced rendering the fat pad and particularly the synovial fringes vulnerable to injury

In which the joint is the subject of degenerative changes The pattern of internal derangements of the knee joint and the age at which they are encountered has changed in material degree in the past two decades (Table 1) This variety is secondary to other pathology in the joint Degenerative changes in the menisci in the form of horizontal cleavage together with thinning of the articular cartilage reduce the space available for the fat pad The fat pad does not decrease in size as the space available to it decreases in size (Fig 2) The liability to injury or to the trapping of synovial fringes is therefore increased

Pathological anaton y

The pathology encountered varies within wide limit The fat pal may be the obvious subject of oedema or of hypertrophy r of fibro is from a previous haemorrhage of traumatic origin It is assumed that fibrosis decreases mobility and renders the fat pad liable to compression If it i enlarged there are usuall pr jections of synovial membrane into the joint and the e may ho v evidence of involvement in trapping incidents

Clinical features

The hi tory is usually of long duration The outstanding symptom i pain or ache in the anterior compartment directly related to physical activity and characteristi call relieved by rest It takes the form of vague retro patellar or retro patellar tendon pain occasionally of sudden stabbing pain which may cause the knee t give way and even of synovial effusions Swelling from hypertrop h ma be pre ent u ually on both sides of the tend n Forcible extension which exerts pressure on the pad may induce pain in the acute phase There ma be local tenderness to deep pre sur

The differential diagnosis includes the range of conditions affecting the anterior compartment of the knee in particular the space occupying lesion

Treatment

If quadriceps insufficiency ontributes in arying degree to the trapping of synovial fringes quadriceps redevelopment is essential in the treatment of every case In circumstances of acute pain and as a temporary measure raising of the heel will take pressure from off the fat pad It is not however a method of treatment which should be maintained because walking on a knee which does not and cannot extend fully is undesiral le

In general when the diagno is ha been established beyond reasonable doubt the treatment to be recommended is operation Relief is effected by excision of the tags of synovial membrane or reduction f the size and positi n of the fat pad as the occasion demands

THE PICTURE OF THE FEMORO PATELLAR JOINT IN RECURRENT DISLOCATION OF THE PATELLA

by *Håkan Brattstrom* (Lund Sweden)

In the femoro patellar joint the lateral c nd le i n rmally m re prominent than the medial one Recurrent dislocation of the patella i l y many authors ascribed to a hypoplasia f the lateral cond le

In order to make these quantities measurable on the X ray film I have under standard conditions examined 100 men and 100 w men with healthy knees and 30 w men with recurrent disl cati n f the patella The patient its on an X ray table with a vertical iron pole between the knees and ankles One X ray film is placed ventrally f r the anteri r plan of the c ndyles of b th kne and one film dorsally f r the posteri r plane (Fig 1) On both films a wire indi te the horizontal line

In this way I get two practically imultaneous films with the anterior plane of right and left knee on n film and the p steri r plane n the ther (Fig 2 schematic)

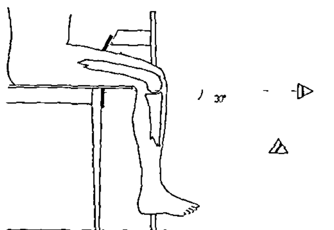


Fig 1

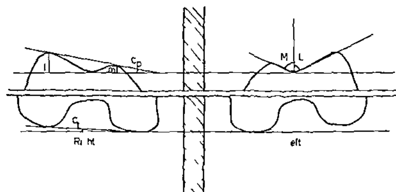


Fig 2

On the films I have measured and calculated the following facts

1 The ratio between the heights of the lateral and medial condyles above the horizontal line through the bottom of the sulcus (Fig 2 l/m)

Ratio l/m (right knee)

Healthy men	1 95 ± 0 07
Healthy women	1 98 ± 0 08
Sick women	2 90 ± 0 54

It seems as if the ratio of women with recurrent dislocation is a little higher than that of healthy women as a sign of a *bigger* predominance of the lateral condyle but the difference is not significant

2 In order to see if rotation or torsion of distal end of femur is of any importance I have measured the angles between the planes through the anterior resp posterior border of the condyles and the horizontal plane (Fig 2 C_p resp C_t) and by this it is possible to calculate the angle C (not in Fig 2) between these two planes

Angle C (right knee)

Healthy men	2.86 ± 0.25
Healthy women	3.48 ± 0.25
Sick women	2.70 ± 0.68

There is no significant difference between these two female groups (0.78 ± 0.73).

3. I have measured the angles between a vertical line through the bottom of the sulcus and the lines from the tops of the condyles to the bottom (Fig. 2, L resp. M). I call them "condyle angles". They are independent of the varying photographic enlargement and give a better impression of the shape of the articulation than talking about the relative or absolute heights of the condyles. If the condyle is low, the angle is big and vice versa.

Condyle angles L resp. M (right knee)

	L	M	L+M
Healthy men	69.3 ± 0.4	73.5 ± 0.4	142.8 ± 0.5
Healthy women	69.4 ± 0.4	72.4 ± 0.4	141.8 ± 0.6
Sick" women ..	75.2 ± 0.7	77.0 ± 1.1	152.1 ± 1.3

The difference between sick and healthy women is for L 5.8 ± 0.8, for M 4.6 ± 1.2 and for L+M 10.3 ± 1.4. This means that in a sick knee the lateral angle is bigger than normal as a sign that the lateral condyle is smaller, but at the same time the medial angle is bigger than normal, and the enlargement of the angle is of about the same size as the lateral one.

Conclusions

The flattening of the lateral condyle which has been described by many authors is real, not depending on rotation or torsion, but it is accompanied by a *flattening of the medial condyle* of about the same size. Instead of talking about the relative or absolute heights of the condyles, it is better to describe *the "condyle angles"*.

RESULTS OF THE PATELLARPLASTY IN SOME SEVERE CASES OF DEGENERATIVE ARTHRITIS OF THE KNEE JOINT

by *Henrik Stören* (Stavern, Norway)

In many cases of painful degenerative *arthritis of the* knee joint, conservative measures are tried without success. We all know these short, obese individuals above 50 years of age, so *commonly presenting* genu varum caused by reduction of the cartilage of the median part *of the joint*. Rather commonly this painful condition leads to abuse of analgetics, and for many patients arthrodesis is the final outlook.

Because of its disadvantage, I feel that arthrodesis should be the very last treatment chosen. Especially in older individuals an already impaired venous circulation may be further reduced by *creating a stiff* knee and thereby reduced activity of the muscles of the thigh.

Comments on Table 2

Excellent denotes ability to perform normal walking and movements without pain Further the ability of 60 degrees or more flexion and nearly complete extension

Good denotes ability to walk without pain on an even floor but not on stairs or rough ground Flexion 45 degrees or more

Fair denotes any definite improvement but where moderate pain is still felt upon walking and a cane is being used

Poor denotes persistence of pain whether mobility has been improved or not

Conclusion

The material here presented is fairly small but I hope it will throw some light upon an operative procedure which may have a beneficial effect in otherwise hopeless cases Even if the operation is of a palliative nature its long lasting effect seems to indicate that it sometimes is able to break a vicious cycle in these patients

QUADRICEPSPLASTY FOR STIFF KNEE FOLLOWING FRACTURES

by *E A Nicoll* (Sheffield England)

PAUWELS OSTEOTOMY IN COXARTHROSIS

by *Sophus von Rosen* (Malmo Sweden)

Fredrich Pauwels doctor of medicine and technology gave a fuller report on his conception and experience of the genesis and the treatment of coxarthrosis in the report from the 48th German Orthopaedic Conference held in Berlin during 1960

Pauwels states that coxarthrosis is a biomechanical problem and is due to the lack of accord between the mechanical demands placed on the hip joint and the resistance to these mechanical demands present in the cartilage and underlying bone tissues The biological component in this lack of accord cannot be safely judged and cannot be influenced by our therapeutical measures The other component the mechanical forces acting on the hip joint can be corrected by operative procedures in the form of a causal therapy

The three operative methods discussed by Pauwels are the Voss operation the Mac Murrey displacement osteotomy and the Pauwels varus adduction osteotomy

According to Pauwels the effect of both the *Voss* operation and *Mac Murrey* osteotomy is a decreased pressure on the acetabular surfaces caused by a weakening of the action of the hip joint muscles Pauwels thinks that these operations are not indicated in cases where the weightbearing surface is limited through subluxation or incongruence between the articular surfaces The varus adduction osteotomy is justified in cases where greater contact between the articular surfaces is obtained when the leg is abducted

Pauwels shows the results in a number of long term cases showing beautiful and I would say fascinating structural improvements in the architecture of the joint

My own experience of the Pauwels varus adduction is based on 17 patients on whom we have performed 20 Pauwels osteotomies since 1956 The sex distribution was 16 females and 1 male It was around 30 years of age that the operation came into use as it was at this age that the patients began to be troubled and then again



Fig 1
Female born in 1901 From 1944 to 1958 a progressing osteoarthritis developed in the left hip joint 1944 (a) 1954 (b) 1958 (c)



Fig 2
Same patient 3 year after varus adduction osteotomy

later after the menopause The two youngest were treated purely prophylactically owing to a valgus and subluxation position after late reduction of hip joint dislocation

With a small modification we have followed the operative technique which Pauwels recommended in 19 5 Our result has been up to now very encouraging

A short review of one as follows

B O ♀ born in 1901 Quite e trouble from the left hip joint in 1944 Had to use one cane for walking Could lr p the ane in 1946 after continuous gymnastic training Some ear later this patient suffered increasing pain which was impossible to endure n 1958 (Fig 1 showing the X ray changes during this period) A

varus adduction osteotomy was performed in March 1959 Present condition The patient is very pleased Mobility 90 flexion 15 abduction 25 adduction Practically no limp The last X ray is very satisfactory (Fig 2)

DELAYED EMERGENCY TREATMENT OF OPEN LESIONS OF THE EXTREMITIES

by *Erin Madsen* (Sorø Denmark)

A report is made on 84 open lesions (all but 5 were lesions of the hand) treated with delayed operation as recommended by Iselin Primary treatment was as follows surgical washing of skin revision of wound excision of dilacerated skin edges no suture dressing moistened with cetaulon chemotherapeutics The dressing is changed daily When acute reaction is decreasing a few days later the final operation is done excision of wound repair of tendons nerves and fractures transplantation of skin suture of the wound dry dressing

The motives for the delayed treatment are generally to operate under the best conditions We can safely use an universal anesthesia a skilled hand surgeon is available After the interval of a few days the limits of the necrosis are clearly to be seen this means that the excision is safer This method allows us to suture nerves and tendons nearly primarily on the fingers also the tendons in no mans land are repaired with the method of *Claude Verdan* suture bloquee" The conditions for skin grafting are favourable Last but not least until now we have been able to avoid serious infections even in gravely contaminated wounds *No tendons bones or joints have been infected*

Skilled experience and close observation during the interval are necessary to decide the optimal moment for operation *The patient must be considered a case of urgency until the operation is done*

Results Of a total of 84 cases 79 healed without infection

25 cases had skin grafts

In 5 cases there was a slight superficial infection but they all healed between 12 and 20 days (1 suture on a finger burst without suppuration 1 skin graft had a slight suppuration along the edges 2 crushed finger ends had slight infections of the nail bed 1 big wound on the leg was slightly infected a few days)

Interval 24 were operated after 18–24 hours 38 between 1 and 2 days 14 between 2 and 3 days 8 between 4 and 7 days

Suture of extensor tendons 14 had very good result 3 had fair results 1 bad result

Suture of flexor tendons 7 had very god results 3 of them were sutured in no mans land with suture bloquée 3 had a fair result 2 of them in no mans land No bad results

(Fair Finger 2–1 cm from palm or ext defect 10 –50)

We started this treatment with scepticism Now we use it with confidence

INDUCTIVE MECHANISMS IN BONE TRANSPLANTATION

by *R Geoffrey Burwell* (Leeds England)

The previous immunological studies of the writer have shown that homografts of fresh marrow free iliac bone are only weakly if at all antigenic

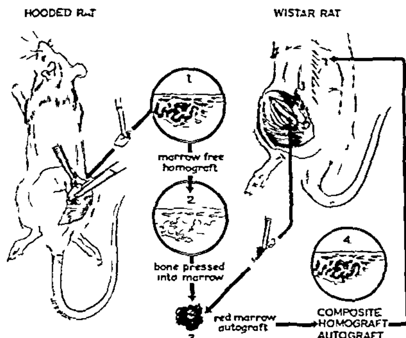


Fig 1

The meth d of preparation of a fre h comp site homograft autograft of cancellous bone

In view of this finding an attempt has been made to pr duce a foreign bone graft capal le of f rming new bone a readily as an iliac autograft b the following me th d (Fig. 1) It wa found that bone and marrow together as a fresh composite homograft autograft (CHA) form considerably more new bone than do either of the c mp nents of the graft transplanted separately Aut grafts of red marrow trans planted al ne to a muscular site f rmed new b ne in 13 of 30 experiments (43 per cent)

The effect of various physical an l chemical treatments of the homologous bone l ef re combining it with fresh autologous marro v has also been investigated U sing a quantitative meth d it was found that there is no statistical difference between the am unt of new bone formed l fre h CHA s and CHA s prepared from b ne treated b freezing (—20 C and —196 C) However CHA s prepared from bone treated b freeze drying freeze-dr ing and irradiati n freeze drying after steriliza ti n with 1 *p r cent β* pr piolactone and l-calficati n f rm signif cantly less new b ne than d fresh CHA s Fin ll the CHA s prepared from bone treated by boiling merthiolate solution organ extra t n and a hing sh an even further impair ment f new b ne f rmation

Thes ob ervati n were di u d briefly in relation t (a) me hani m of steo gene is (b) the l ne b nk ( ) f cture healing and (1) the significance f the relati n f b ne an l m rr w



Figs 1 2 and 3
Dysplasia epiphysialis capitis femoris

Fig 1 1 11/12 year old boy 11 months before the first roentgenological and clinical signs of Dysplasia Ossification of the epiphysis retarded at least 1 year

Fig 2 The same Patient 11 months later The nucleus of ossification appears dysplastic

Fig 3 The same Patient 5 months later than 2

homogenous group There is a minor group presenting a disease picture—a syndrome—which is distinct both roentgenographically and clinically from the classic form of Perthes disease—not least as concerns prognosis

This disease picture is found in only about one tenth of all the patients and mainly in *children under 4–5 years of age* The epiphysial changes are not seen in *normally developed epiphyses as in typical cases of Perthes disease but in small very strongly retarded epiphysial nuclei* The roentgenogram shows no stage of condensation or fragmentation From the very start the small retarded epiphysis shows a *diffuse more or less coarse grainy bone structure* This "grain of rice" structure is most pronounced in the very earliest stages Then without going through a stage of fragmentation the structure becomes slowly and gradually more homogenous The size and bone structure of the epiphysis become normal in the course of *three years* and following suitable non weight bearing treatment healing ensues with no epiphysial flattening so that the final result is a *completely normal epiphysis*

In contrast to this healing in Perthes disease takes about 5 7 *years* the disease leaving its trace in the form of a more or less *deformed epiphysis*—depending on the treatment To distinguish it from the classic form of Perthes disea e a suitable designation for the above disease picture would be Dysplasia epiphysialis capitis femoris The fundamental difference between the two syndromes *is presumably that* while the dysplasia only is the expression of a *disturbance in ossification* of the young epiphysis Perthes disease is the result of *a real necrosis* of the head of the femur

The roentgenographic picture found in dysplasia of the head of the femur closely resembles the epiphysial changes so often found in *congenital dislocation of the hip*—before any attempt at reduction None of the present cases of dysplasia of the head of the femur however showed luxation subluxation or dysplasia of the acetabulum Nevertheless it seems likely that a pathogenetic *relationship exists between congenital dislocation of the hip and dysplasia of the head of the femur*

Dysplasia of the head of the femur *on the other hand* is often *associated with the classic form* of Perthes disease either in the *same* patient in the *same* family or in the form of transitional cases The dysplasia also seems to *predispose to classic Perthes disease later*

Dysplasia and Perthes disease are therefore *undoubtedly not two different diseases* but merely an expression of the same cause resulting in different reactions in early and late childhood

If the common pathogenesis of the two syndromes is disturbances of epiphysial circulation—and much tells in favour of this—*Trueta s studies* of vascularization of the epiphysis of the head of the femur in various age groups provides a natural explanation of the difference in the effect of circulatory disturbances before and after the age of 4–5 years

DISCUSSION

E G Her og (Sheffield England)

I was extremely interested in Dr Me er s paper

Since as we all know it is so difficult to arri e at a definite prognosis in Perthes disease it seems very likely that we are in fact dealing with different types of cases so that when we compare different f rms of treatment our series are not strictly comparable Now Dr Meyer has taken a whole group of patients out of this disease c mplex under the name of d splasia epiphysialis and p e umably they have a different progn sis and p ssibly require different treatment With a similar idea in mind I have recentl scrutinized more closel several cases which did unexpected l badly with treatment by prolonged immobilization which on the whole we con sider the treatment of choice We f und that in two of them we had to revi e the diagnosis to one of osteochondritis dissecans We opene l the j int in one of these cases and found a fragment which we freshened and pinned back with two Smillie pins

THE MECHANICAL EFFECT OF THE CALCANEUM IN RELATION TO DEFORMITIES OF THE FOOT

b *F C Duyer* (Liverp l England)

Having noted the pr gre i e impr ement f ll wing plantar fasci tomy and c rrection of the varus of the heel in pe ca u a l antage ha l n t ken of ther deformities t tudy the effects n the f ref t f alt ring any al n rmalit in size or inclinati n in size or inclination f the cal aneum

Attention i drawn t the l ne of action f the Achille tend n (actuated as it is l the two mo t powerful mu cles in the calf) in the norm l Any abn rmalit in the nclination f the calcaneum will shift the line f action f the tend n thus accentuating the d f rmity and affecting the balance and shape of the wh le fo t Weakness r l of p er in the calf re ults in the calcaneum projecting di tally like a po t r lily rolling into valgus r varus

The prin ip l s und rl ing operative correction in all deformities including paralytic ones r basicall the same The c n i t in orrecting th al n rmal incl nation of th l l b remo ing or in erting w lge f b ne an l increasing r de crea ng th h ght f th heel where nec r

Walking with the heel stable and fully corrected (or in some instances over corrected) results in gradual correction of the forefoot deformity to such an extent that the following conclusions have been drawn

1 No tendon transplantation should be performed before observing the full effect of altering the shape and inclination of the heel
2 With the exception of paralytic drop foot mid tarsal wedge resections can be avoided Any equinus or supination of the forefoot which persists in spite of heel correction can be dealt with by removing a wedge at the tarso metatarsal level leaving the mid tarsal joint intact

In pes cavus in paralytic varus deformities and in club foot after division of the plantar fascia balance is achieved by either removing a lateral wedge from the calcaneum when the heel is large or inserting a wedge into its medial aspect when it is small as in club foot (the Achilles tendon being lengthened at the same time)

In all valgus deformities and particularly in cerebral palsy the insertion of a *wedge of bone into the lateral aspect of the calcaneum tilts its plantar surface into* varus and prevents it from rolling into valgus The effect of control of the hindfoot by this means exerts a balancing effect upon the forefoot In cerebral palsy the alteration in proprioceptive impulses is reflected higher up in the reduction of adductor and flexor spasm thus exerting a profound influence on balance and gait

In calcanean deformities the height of the heel is reduced by removing as large a wedge as possible from the postero superior aspect of the calcaneum at the same time correcting any valgus or varus inclination When the calf is completely paralysed the wedge of bone which has been removed is inserted into the neck of the talus where it acts as a very effective bone block preventing excessive dorsi flexion

PARALYTIC CALCANEO CAVUS DEFORMITY OF THE FOOT

by *E W Somerville* (Oxford England)

Paralytic calcaneus deformity of the foot can be divided into three types In all three the gastrocnemius and soleus muscles are paralysed the extent of the paralysis of the other muscles determines the degree and type of deformity that results

Type 1

The gastrocnemius and soleus are the only muscles which are paralysed all the other muscles are acting strongly As a result the heel assumes the vertical position because there is no upward pull but the other muscles of the calf pull the forefoot down producing the exaggerated cavus deformity Whenever this muscle imbalance exists the deformity of calcaneo cavus will always follow It can be prevented or corrected by a suitable tendon transplant in which all the active muscles of the calf and the peroneal muscles are implanted into the end of the tuberosity of the calcaneus as tightly as possible and the foot immobilized in plaster for one month Of 13 such operations the result has been successful in correcting *the deformity* and improving function in 12 4 of these patients are able to walk on tip toe

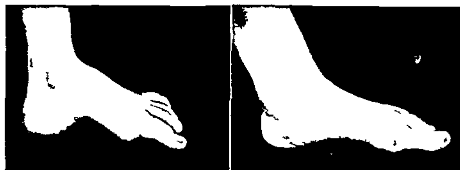


Fig 1
A calcaneo cavus foot treated by tendon transplant

Type 2

In this type all the muscles of the calf are paralysed but the dorsi flexors are acting and the tibialis anterior is often over acting With this muscle imbalance the calcaneus is as in Type 1 but the cavus deformity is less marked However the disability is greater because the forefoot cannot be got down to the ground It is treated by transplantation of the tibialis anterior through the interosseus membrane into the calcaneus again as tightly as possible along with the peroneal muscles if they are acting This operation has been done three times all were successful in the first place but in one at the end of one year the tendon of the tibialis anterior ruptured spontaneously

Type 3

Where all muscles below the knee are paralysed The calcaneus is of moderate extent and the cavus deformity is minimal This foot can only be improved by stabilization operations involving perhaps arthrodesis of the ankle or bone block

INDICATIONS FOR SURGERY IN SPASTIC PARALYSIS

by W J W *Sharrard* (Sheffield England)

Operative treatment has an important place in the management of children with spastic paralysis for the correction of fixed deformity and the redistribution of muscle forces at a joint Reluctance to advise an operation often arises from fear of making a patient's condition worse or no better An investigation was made among 420 spastic children to discover a reliable means of determining the indications for and the correct application of operative treatment

The development of deformity in spite of adequate physiotherapy was found to be related not to the presence of spasticity in the shortened muscle but to relative weakness of voluntary action in the muscles opposing the deformity Thus equinus was associated with relative weakness of the ankle dorsiflexor independent of the level of spasticity in the calf muscle Flexion and adduction deformity at the hip level pel ... h n the gluteal muscle ... ere we k ... nd flexion at the knee when the quadriceps was weak A *suggested mechanism for the development of deformity* ...

that the shortened muscle has failed to grow because of diminished tension exerted on it by its weaker opponents

The rationale of surgical treatment should be to correct muscle length and if possible to obtain a better balance of forces at the affected joint Tendon elongation or division weakens the stronger muscle and frequently achieves both aims partial neurectomy or tendon transposition may also be used to obtain muscle balance In addition to well known procedures three operations new to the surgery of spastic paralysis have been found to be useful These are psoas tendon elongation for hip flexion deformity posterior ilio psoas transposition for incipient dislocation of the hip and alternate anterior and posterior rhizotomy for spastic scoliosis

TUBERCULOSIS OF THE SPINE TREATED WITH ANTITUBERCULOUS DRUGS AND RADICAL OPERATION WITHOUT ENFORCED RECUMBENCY IMMOBILIZATION AND LONG HOSPITAL STAY

by *Bernhard Paus* (Oslo)

100 patients were given this treatment at the South Korean Scandinavian Hospital in Seoul Korea INH and PAS were used with addition of SM only during the in patient treatment

The patients were admitted and operated as soon as the bed capacity permitted The operation aimed at as thorough eradication of the lesion as possible No bone grafting was used No tube was left for postoperative local instillation of drugs

The patients were permitted to get up as soon and as much as they wanted even if this meant the day after operation Altogether 43 patients were completely up and about within 3 months

Immobilization with plasterbeds jackets and corsets was substituted by active exercises starting from admission

The in patient treatment averaged 35 days with a maximum of 30 days in 55 % 40 days in 70 % and 60 days in 90 % These figures include pre and postoperative treatment possible prolongations because of intercurrent diseases postponing opera tion additional operation for tuberculosis of the hip knee sacro iliacal joint pubic bone treatment for pulmonary tuberculosis etc

The patients were included without any selection The average number of verte brae affected was 4 1 *Paraplegia was present in 21 cases sinus in 21 pulmonary* tuberculo is in 31 etc

80 patients became completely able to work For adult males this mostly meant farm work or unskilled labour For adult females it mostly meant housework The interval from operation to resumption of work was less than 3 month in 15 case and less than 6 months in 47 cases Roentgenological improvement was found in 80 % and block in 60 %

2 serious complications occurred with operative damage of the cord The operative mortality was 1 %

The kyphosis amounted to the same degrees and increased in the same way as with other treatments

CONGENITAL HIP DISLOCATION A FOLLOW UP STUDY

by *Ib Christensen* (Aarhus Denmark)

THE RECOGNITION AND CURE OF CONGENITAL FLAT FOOT

By *Denis Wainwright* (Newcastle England)

The distinguishing X ray features of a true congenital flat foot are the vertical alignment of the long axis of the talus and the equinus deformity of the calcaneus. The forepart of the foot remains dorsiflexed resulting in a subluxation of the talo navicular joint

In this comparatively small series of cases diagnosed in infancy (8 in all) the deformity has been corrected by repeated manipulations of the forepart of the foot in a downwards and medial direction to bring it into line with the axis of the talus and when this was accomplished the equinus of the hind foot was corrected by an elongation of the tendo Achilles and a posterior capsulotomy restoring the longitudinal arch of the foot. In some cases this could only be achieved by placing a spike in the os calcis and levering the heel downwards and incorporating the spike in the plaster

Fig 1a shows the X rays of a child with bilateral congenital flat feet at the age of twelve weeks. They show a completely vertical position of the talus with equinus deformity of the os calcis and dorsiflexion of the forepart of the feet. The antero posterior view illustrates the medial deviation of the talus (Fig 1b)

Fig 2 is a lateral X ray of the right foot showing the extreme degree of equinus of the forefoot necessary to re align it with the talus. Subsequent lengthening of the tendo Achilles and posterior capsulotomy corrects the equinus of the calcaneus and fully restores the longitudinal arches (Fig 3)

If the diagnosis can be established in infancy and provided the condition is not associated with a severe degree of generalized arthrogryposis or spina bifida careful



Fig 1a



Fig 1b

Fig 1a [illegible] view showing vertical talus and equinus deformity of the [illegible]

Fig 1b Lateral view showing the gross medial displacement of the [illegible]



Fig 2



Fig 3

Fig 2 Lateral view showing the extreme degree of equinus necessary to re align the forepart of the foot with the talus

Fig 3 Lateral view of both feet showing the full correction of the deformity of both feet with restoration of the longitudinal arch

and intensive treatment on the lines suggested can result in a complete cure of this rare but troublesome and intractable deformity

SCOLIOSIS SYMPOSIUM

THE PATHOGENESIS OF EXPERIMENTAL PROGRESSIVE SCOLIOSIS

by A *Langenskiold* and *J F Michelsson* (Helsingfors)

In order to provoke progressive scoliosis different operations on muscles nerves and bones in the vicinity of the spine and on the spine itself were performed in young rabbits and pigs It was found that progressive scoliosis always occurs when the posterior ends of 4–5 ribs are removed on one side After hemilaminectomy of 4–5 thoracic or lumbar vertebrae of growing rabbits scoliosis of 50–180 degrees developed in 2/3 of the animals (Figs 1 and 2) The fact that both these operations cause severe scoliosis pointed to the existence of a common factor in these two apparently entirely different procedures

It was found that the common factor in the two operations is the loss of function of the posterior costo transverse ligament One third of the animals subjected to section of five posterior costo transverse ligaments developed progressive scoliosis In the other two thirds of this group scar formation prevented the deforming effect of the operation The permanent loss of function of posterior costo transverse



Fig 1

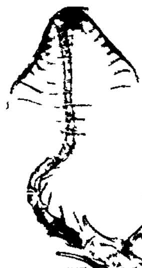


Fig 9

ligaments seems to be the scoliosis provoking factor after hemilaminectomy and after rib resection

We concluded that a protracted unilateral insufficiency of the function of the posterior costo transverse ligament at several levels of the spine of a growing rabbit or pig causes progressive scoliosis of the same type as is seen in man This ligament in transmitting the effect of normal muscle tone to the spine is of decisive importance to its equilibrium and symmetrical growth Loss of function of the ligament on one side is followed b contracture of the corresponding ligament on the other side This contracture is soon followed by contracture in other structures

It is obviou from the anatomy of the posterior costo-transverse ligament that a contracture of it leads to a deformity composed of lateral flexion and rotation of the spine

Rabbits with a scoliosis of up to 70 degrees could be brought t grow straight in the course of some weeks by mean of section f the costo transverse ligaments and parts of the interco tal muscle on the concave side of the primary curve

THE ROTATION IN IDIOPATHIC SCOLIOSIS

by *Olof Lindahl* (Stockholm)

In a study in ollab rati n with Raeder we have analy ed the l cation of possible forces that—fr m a purel mechanical point of iew—can produce the different deformities that characterize idi pathic scoliosis (Acta Orth Scand 3? 27 1962)

As a result f this analysi resecti n f the transversal proces es n the concave side of th rve was a um d to be a method of obtaining regression of the curve

This op ti n has been p rforme l in 13 c s of idiopathic thoracic scoliosis and the pati nt ha e been b rved f r l etw n 9 and 24 months It was concluded that this op ti n di l n t thu f r infl en e the natural cour e f the disease

However according to this mechanical theory other structures might also produce the same deformity and the next most likely structure would be the thoracic wall especially the posterior part A unilateral restriction in vertical growth of the thoracic wall might be the cause of thoracic scoliosis

An elongation of this structure on the concave side is now being tried as a new attempt to correct the scoliotic curve

DISCOGRAPHY IN EARLY CASES OF IDIOPATHIC SCOLIOSIS

by *Olof Perey* (Örebro Sweden)

In spite of considerable research the aetiology of idiopathic scoliosis is as yet unknown and hence it follows that the treatment is symptomatic In the more recent literature many maintain that the scoliosis is consequent on changes in the vertebral development Greatest attention has been focussed on the epiphyseal ring but as recently described by *Stillwell Jr* these changes are secondary Prof *James* has demonstrated that no changes were visible in the epiphyseal ring of an eleven months old child with scoliosis

My opinion is that idiopathic scoliosis has a congenital aetiology in spite of the fact that it sometimes appears quite late in life This is supported by the fact that it appears in uniovular twins *Murdoch* has published one case and I quote another

The complicated development of the spinal column from several centres which ultimately units in the adult spine leads to the frequency of congenital deformity Developmental abnormalities in the vertebrae are apperent roentgenologically but disc deformities cannot be visualized by normal straight X ray films

In idiopathic scoliosis there is no primary deformity of the vertebra and thus the disc must be examined for the presence of anomaly In young individuals the moving centre lies in the nucleus pulposus which is under pressure and as the nucleus and annulus develop from different centres it may be suspected that the nucleus is abnormally placed in the disc It is known that the nucleus can displace laterally due to changes in intradiscal pressure and consequent vertebral remodelling

In a series of cases of newly developed scoliosis which have been sent to me by my colleagues in the children welfare service three cases were suitable for discography The remainder were either thoracal or thoraco lumbar in which it was technically difficult to perform discography without risk The investigations were carried out according to the Lindblom method using the so called Antoniueedle The patients were 14 12 and 2 years old respectively Discography showed that at the apex of the scoliotic curve the nucleus was located asymmetrically In two it was dislocated laterally to the convex side and in the other case to the concave side The other discs examined had a centrally placed nucleus

The three cases examined showed early scoliosis not exceeding 15 and all subsequently decreased—the oldest least and the youngest most In the two year old girl a fenestration of the disc and removal of the nucleus was performed through an abdominal incision Post-operatively the scoliosis decreased over the nine months after the operation

I feel that it is necessary to operate in these cases as early as possible before secondary changes in the epiphyseal ring and deformities in the vertebral body and pedicles occur Once these deformities have occurred the balance is already lost and

thus epiphysiodesis or fusion on the same indication as previously must be performed with the subsequent greatly increased treatment period

TRANSTHORACIC APPROACH FOR VERTEBRAL EPIPHYSEODESIS

by *Ulf Nilsonne* (Stockholm)

(To be published later in the Acta Orthopaedica Scandinavica)

THE LATE RESULTS OF UNILATERAL GROWTH ARREST OF THE SPINE FOR SCOLIOSIS

by *Robert Roaf* (Oswestry England)

Whatever the primary cause of a spinal deformity there is always a continuing or secondary cause—namely the disturbance of growth leading to deformity both of the bones and intervertebral disks The exact site of growth inhibition determines the type of curve Fig 1 shows that if the growth inhibition is anterior a kyphosis results if antero lateral a kypho scoliosis if lateral a lateral flexion deformity without rotation if postero lateral a lordo scolio is with varying degrees of rotation There will be over growth of bone opposite to—that is at 180 degrees to the site of growth inhibition

The logical treatment of growth disorders is to perform a gro th arrest operation at the appropriate site—that is opposite to the site of growth inhibition

It has been found that an antero lateral approach is the mo t flexible in enabling one to site the growth arrest either more anteriorly or more posteriorly according to the type of curve

So far the results have been very encouraging—out of 189 patients deterioration

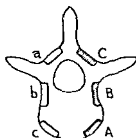
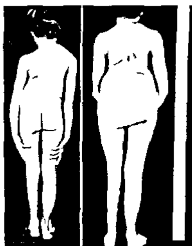


Fig 1



a b

Fig 2

a Progressive paralytic curve
b Six years after growth arrest

in progressive curve ha been stopped and in every case and in approximately half there has been decrease in the curve with further growth

In half the patients re explorations have been performed and in only one has there been a pseudarthrosis at the site of the epiphyseodesis Typical examples of improvement with growth are shown

THE MANAGEMENT OF SCOLIOSIS

by *J I P James* (Edinburgh Scotland)

The only effective treatment of scoliosis is spinal fusion By no means all curves are serious enough to require this and yet if we delay too long to see what happens the deformity becomes largely uncorrectible particularly the rotation

To resolve this dilemma it is necessary to know the natural course of the various aetiologies and types of curves In those with a bad prognosis we undertake fusion at the earliest stage if the child is over ten If under this age and therefore probably too young for fusion the Milwaukee brace is most effective in preventing all further deterioration until the child is ready for fusion

At all ages curves with an expected benign course are solely maintained under observation

In a study of scolioses who were skeletally mature but who had never had effective treatment it was possible to analyse the behaviour of many types of curve

In all aetiologies it was clear that high curves (thoracic) had a poor prognosis whereas those lower in the vertebral column particularly the lumbar curves were rarely serious The age at which the curve appeared had a lesser but well marked influence As is well known paralytic curves and those arising in neurofibromatosis have a generally more serious outlook than idiopathic curves though almost all thoracic curves in this aetiology were serious The behaviour of congenital curves was hard to predict many were slight a few produced grotesque deformity

Using bone bank bone the pseudarthrosis rate on exploration of the graft was about 50 % A change to the technique described by *Moe* had resulted in a fall 10 %–15 % Routine exploration of the fusion five months after fusion allowed absolute certainty of fusion or failure If a pseudarthrosis existed it could then be repaired without loss of correction and adding only two months to the period of immobilization

SURGICAL TREATMENT OF SCOLIOSIS

by *Ivar Alvik* (Oslo)

Because of the drawbacks of the long lasting immobilization in a heavy plaster jacket confined to bed for many months and because of the inconvenience of performing the operation through a window in the jacket as is usually done in the ordinary methods of scoliotic fusion we have developed our own method for fusion of the increasing scoliotic curve

The main principles in this method are

1 The curve is mobilized by means of physiotherapy (Contracture therapy)
2 After having obtained the best possible mobilization a plaster jacket is applied in a standing position in a gallow with suspension and side traction
3 Further correction of the curve by means of ordinary wedging of the jacket

4 The corrected plaster jacket is carried for several months and is ver often changed after another seance of mobilization
5 Before the operation the plaster jacket is removed giving access to the operating field
6 The fusion is performed in the socalled knee—elbow position to facilitate the operation and to minimize the bleeding The fusion is done in one stage and the whole curve is included in the fusion A large amount of bone bank bone is used as ships
7 After the operation the patient is placed back in bed without any plasterjacket and without anye corrective spine support
8 The patient is let out of bed in the course of the first three or four days after the operation without any spine support
9 As soon as the patient is able to stand in the gallow for at least 20 min (usually 14 days p o) he is replaced there and another plaster jacket is applied in the same way as before the operation and corrected by wedging
10 With this plaster jacket the patient is sent home can walk around attend school and maintain activity
11 The plaster jacket is worn for 9 months

From 1952 till 1960 152 patients were treated at Oslo University Orthopaedic Hospital with fusion of the scoliotic curve and most of them according to the above described method More or less correction is obtained in about 80 % The average loss of correction after removal of the postoperative plaster jacket is 6 3 degrees included 9 cases (5 9 %) of pseudarthrosis No death has occurred postoperativel

CARDIO PULMONARY FUNCTION IN SCOLIOTIC PATIENTS TREATED WITH SPINAL FUSION

by *H Erikson* and *M Foss Hauge* (Oslo)

At the University Orthopaedic Hospital in Oslo rather extensive spinal fusion is used for the surgical treatment of scoliosis

Since scoliosis deformity usually invol es the thoracic cage it was considered of interest to study the cardio pulmonary function *b fore* and *after* the performed fusion

41 patients from 8 to 17 ear of age were examined at the Uni ersity Institute of Respiratory Physiology in Oslo pre-operatively and 9 months after the operation (a few days after removal of their plaster of Paris)

Besides the conventional determinations of vital capacity and maximal breathing capacity a special test for determining the total cardio pulmonary function introduced by *Harald Erikson* was used By means of a spirometer constructed by *Erikson and colleagues* the CO output was determined during rest during a standard exerci e and the recovery phase The time required from the end of the exercise till the CO -output regains the resting le el is called *the CO recovery time* It is measur l in minutes and is an expression of the cardio pulmonary function

The pre p rative determinati ons of vital capacity and maximal breathing capacity show that alm t all the patients h d capacit bel w the normal mean values and s me onl al ut 25 per cent of the e (comp re l with mean values for healthy chil lren n a erage height an l weight n Oslo)

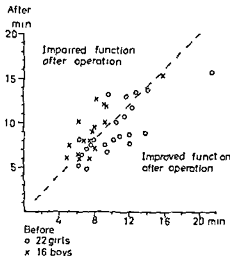


Fig 1

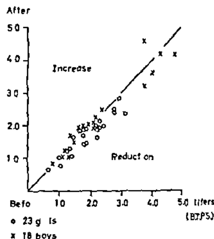


Fig 2

The CO recovery times are prolonged for the majority of patients indicating a decreased cardio pulmonary function Two patients with recovery times of more than 15 minutes were—according to this test and also according to clinical evaluation—cardio pulmonary cripples

In general the preoperative examinations showed that the bellows function of the lungs and the total cardio pulmonary function in these patients varied from normal to very poor with mean function values approximately one half of normal

A comparison of the values obtained before and after the operation is made Fig 1 shows the data on vital capacity which demonstrates only small or no changes The same is the case for the data on maximal breathing capacity and for the CO recovery time shown on Fig 2 On the graphs observations showing no change after operation fall on a line at an angle of 45 degrees

In conclusion we have found that surgical correction of scoliosis *in the first instance* has *not* led to an improvement in cardio pulmonary function as we had hoped But neither has it led to further impairment as we feared

The investigations will be continued and the patients followed for many years with the same cardio pulmonary tests—and perhaps this will throw some light on to the important clinical problems concerning pulmonary heart disease

SCOLIOSIS TREATED WITH SPINAL FUSION

by *Erik B Riska* (Helsinki)

The treatment of progressive structural scoliosis in the Orthopaedic Hospital of the Invalid Foundation in Helsinki was reviewed on the basis of 197 patients operated on during the period 1945 to 1961 In this series of patients 86 had idiopathic scoliosis 99 had paralytic scoliosis and 12 were miscellaneous cases

The majority of the patients underwent operation between the ages of 13 and 15 The turnbuckle cast of *Risser* was used from 1947 to 1954 in 47 cases the Milwaukee

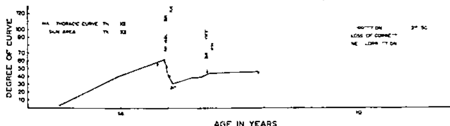




Fig 1

brace of *Blount* & *Schmidt* from 19 4 in 15 ca es Three general t pe of fusi n have been empl ed b about 20 different urge n fir t the original *Hibbs* method in 23 cases secondl in 24 ca es a meth d of fusi n imila t this but n t in l ing destruction of the arti ular facets Thirdl ince 19 4 the fusion ha been d ne by means f the *C bb* meth d f r 96 patients with the a lliti n f h m gen u b ne bank l ne for 40 patients with aut gen u bone and f r 14 patients with both together The mean du ati n f the foll w up peri l was 3 ears and 11 m nths

The result f tre tment betw en 1945 and 1954 were po r when c mpared with the re ults a h eve l ince 19 7 and l pre ent da treatment It wa l erved that autogenous b ne w uperi r to b ne bank b ne a a grafting material The e were 57 patient ith p udarthr e but it is b i us that more patients suffered fr m un erified p udarthr es *Only 5 patients of the 40 tr at l with fusi n ini li ing aut g n u b n ha l a pseu larthros s in th grafts*

Figur l llu trate our current tr atment This c e i an ad le cent idiopath c liosi t ated with pinal fu i n utilizing a lliti n l autog n u l ne The

gression of the deformity was interrupted by the treatment and a net correction of 24 per cent was achieved In our clinic today we try to get the patient under early treatment We fuse the spine if the deforming curvature attains an angle of 40 50 and mainly with additional autogenous bone

RESULTS OF SPINAL FUSION IN SCOLIOSIS

by *E Thomasen* (Aarhus Denmark)

THE MILWAUKEE BRACE IN NON OPERATIVE SCOLIOSIS TREATMENT

by *Walter P Blount* (Milwaukee Wisconsin)

The pages of medical history record a great many ways of treating scoliosis without operation Some have shown temporary promise only to fail later Until recently none has succeeded in obtaining and maintaining significant correction in a series of cases Braces that allowed ambulation were removed during sleep They provided either lateral pressure or distraction but usually not both If an occasional scoliosis was improved support was abandoned from the weakened torso too soon and the correction was lost

From 1947 to 1956 we used the Milwaukee brace occasionally to correct early paralytic scolioses Acceptable idiopathic curves in girls who were near maturity were improved by wearing the brace with only a single pad The curves became compensated as the major one decreased in length and degree while the lower curve shifted farther across the midline At the same time the rib hump diminished in size

For ten years we discouraged the more general use of the brace in the non operative treatment of idiopathic scoliosis Then we could no longer ignore its potential in correcting these progressive curves Crooked spines have an inexorable tendency to become worse with growth

If the forces are reversed during childhood and efficient active correction is maintained long enough these spines will grow straight again The growth zones on the concave side must be decompressed while those on the convex side are compressed This reversal has been noted in our X ray studies confirming the original clinical observations of *Hueter & Volkmann Stillwell* demonstrated these phenomena experimentally in monkeys in June 1962

The effectiveness of the brace is well demonstrated by a girl with a chronologic age of 13 years plus 6 months The photographs show well compensated curves but with rotation and a high left shoulder that are not acceptable In the X ray the curves measure 45 and 35 (Fig 1)

She wore the brace for three years with good correction and then began removing

---

Figs 1–2

A Female aged thirteen years six months

B Three and one half years later She wears the Milwaukee brace only at night

A December 24 1958 Rapidly progressive idiopathic scoliosis Age thirteen years six months

B July 3 1962 Three and one half years later at completion of treatment



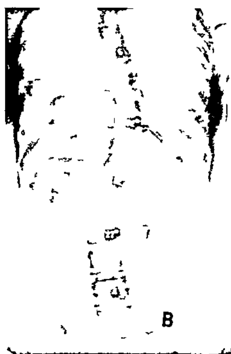
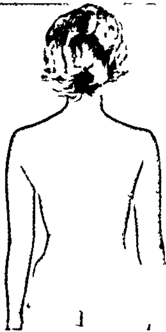


Fig 1





F

it once a week for social functions After four years the improvement was well maintained and she wore the brace only at night (Fig 2) Most of the correction was maintained and there was a pleasing cosmetic effect with almost complete reduction of the rib hump

Ambulatory non operative treatment requires

1 An efficient brace
2 An experienced orthopaedic surgeon
3 The closest cooperation from the patient

The more important components are

1 Efficient distraction This means comfortable but inconspicuous inclusion of the head and an efficient grip on the pelvis The patient can always raise his chin from the support while he takes the weight on the occiput
2 Two to four adjustable pressure pads must be porperly placed under X ray control The orthopaedic surgeon must check the progress at intervals of one to two months and shift the pads as active correction progresses
3 Brief removal of the brace for bathing or swimming is greatly appreciated in hot weather Otherwise it is worn constantly
4 Vigorous activity is encouraged in the brace Volley ball tennis and bicycle riding are common place
5 Specific breathing and posture exercises become meaningful when done in the brace
6 Rest periods must alternate with exercise Total recumbency may be advisable during the first two or three weeks of treatment
7 The brace is worn until the curvature no longer has any tendency to progression
8 Weaning must be gradual after the corrected spine is stable The brace is worn at night only for the last six months or more to maintain the over corrected position while flexibility is regained

Pressure of the pads is made in a cephalad direction against only the ribs that are caudad to the apex of the curve This avoids increasing the superior compensatory curve In overcoming the rib hump the pressure in the anterior direction must not accentuate an existing thoracic lordosis The major pad is placed lower than one would think Frequently the strap that controls the pad is passed behind the posterior upright instead of in front of it so as to develop straight lateral pressure The patient can shift his body away from the pad at all times Special pads are necessary for the less common types of scoliosis

Jaws do not become deformed if one avoids the cup shaped chin piece Protrusion of the incisors occurs in about half of the children This troublesome complication is being well handled by the orthodontists With their appliances it is now possible to correct crooked teeth simultaneously with crooked backs

Progressive structural curves in young children merit a thorough trial of the Milwaukee brace without operation We know that the brace will correct these curves when combined with recumbency after fusion If we keep these youngsters in bed in the brace without fusion for a few weeks their curves develop enough stability to permit gradually increasing ambulation We have successfully weaned young children before puberty They have grown straight as they once grew more and more crooked

Early paralytic scolioses can be corrected and kept from worsening while the muscles become stronger and the fascial contractures subside The brace may be worn while we do release operations and fascial transfers In a significant number of cases the temporary use of the brace from one to six years has been most rewarding

CONFERENCE ON "BASIC STUDIES IN RELATION TO OSTEOPOROSIS

ACCRETION RATES IN OSTEOPENIA STUDIED WITH Ca[45] AND Sr[85]

by *J F Dymling* (Malmo Sweden)

Albright & Reifenstein (1) postulated a humorally effected decrease of bone matrix anabolism as the cause of osteoporosis However they did not have any means to measure bone formation Their concept has lately been challenged (2 3 4)

The accretion rate which can be estimated with bone seeking isotopes (5) is directly proportional to the bone formation rate in normally mineralized bone The accretion rate has been estimated in 56 individuals with osteopenia ("too little calcified bone") and compared to 24 normals (Fig 1) The results are expressed in liters of plasma which can be converted to grams of calcium by dividing with a factor of ten since these individuals are all nomocalcemic (1 gram of calcium in 10 liters of plasma)

The normal 24 individuals had a mean accretion rate of 4 6 ± 0 2 liters of plasma

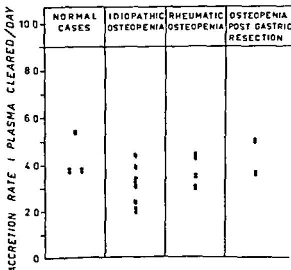


Fig 1

Accretion rates in normal and osteopenic subjects

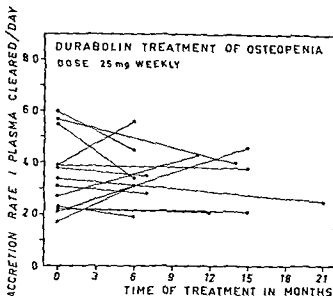


Fig 2
The effect of long term treatment with Durabolin ® on accretion rates in osteopenic subjects

cleared per day In the cases of osteopenia associated with rheumatoid diseases and the idiopathic group the mean accretion rates were 3 7 ± 0 35 and 3 4 ± 0 19 liters of plasma cleared per day This decrease which approximates 30 % is significant In the gastrectomized patients with osteopenia the accretion rate did not differ significantly from the normal group the mean value being 5 1 ± 0 37

The diagnosis of osteopenia was made on X ray It is established that the loss of skeletal mass under these circumstances exceeds 30 % The accretion rates per unit *skeletal mass were thus found not to be lowered in osteopenia In the gastrectomized* patients it was even found to be increased

Treatment of ostepenia with anabolic steroids is based on the *Albright Reifenstein* concept It has been shown that anabolic steroids can reduce calcium loss but it is not established that this effect continues during long term treatment 14 patients with idiopathic osteopenia were studied before and during treatment with 19 nor testosterone phenyl propionate 25 mg weekly for 6–21 months 12 improved subjectively All the females developed hirsutism The accretion rates showed no change (Fig 2) nor did the exchangeable calcium spaces This has been interpreted to mean *that this anabolic steroid does not alter the bone formation rate*

References

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5 *Bauer C C H* *Carlsson A* & *Lindquist B* Metabolism and h me stati fun ti n of bone Mineral Metab lism I Academic Press Inc 1961

THE USE OF TETRACYCLINES AS MICROSCOPIC BONE MARKERS IN THE QUANTITATIVE STUDY OF BONE FORMATION

by *W R Lee* (London)

The tetracycline series of antibiotics have the property f forming a flu r cent c mplex on growing surfaces of bone If bone formation c ntinue the c mplex is built into the bone and remains there its l calizati n can be demonstrated by the mi ro c pic examination of undecalcified section in ultra i let light

If single doses are given at known time intervals a erie f fluorescent mark r are deposited and can be used to determine a) the Appositional Growth Rate and b) the Total New Bone Formati n Rate

a) The Appositional Gro th Rate usuall xpresse l in m crons per da i the rate at which b ne is laid do vn on individual urface It i dete mined b mea urin the linear di tance between the marker u ing a alibrated e epie e micr meter scale

b) The T tal New B ne Formation Rate i th at at which n w b ne i a lde l to the t tal mass and it i usuall expre ed a the pe ent ge f this ma adde l ea h day When appo ition and re orpti n are n equil brium the T t l New l one Formati n Rate is de cribed as Turn ver A tual dete minati n f the T tal New Bone F rmation Rate involves measur m nt in a thin ecti n f the area f l ne f rm d in the period l etween tw mark r l (i e the area f b ne cir um cril e l by the two markers) and the t tal ar a f b ne p e nt Thi can l e carr l out l) by a photographic meth d or l an l m mpling meth d u ing either an eyepi ce grid of the Chalkley type r th L itz Integr ting E ep ece Micr meter

S me results l tained with thi te hn que in th tud of human l ne l th n rmal and in Paget disea e re g en An erim nt l mpari n in the log f cal ium accreti n a ndi ate l b th upt k f C nd t t l new l ne for mati n rate wa de ril d nd d u l

THE EFFECT OF IMMOBILIZATION ON THE RATE OF UPTAKE OF PHOSPHORUS IN MICROSCOPIC BONE STRUCTURES

by *J Strandh* and *A Bengtsson* (Up l Sw l n)

Chang in l ne ti ue pr lu e l b imm l l zati n have l een tu lied l y a numb r of in t gat n u w u ing f r in tance ra li l g hi tol gical r micr ra li h t chniqu ch m e l n l g avimetric d t rminati n r ri l l ty mea m nt

Th aim f th i nt in tig ti n w t tu l the influen e of imm b li ati n with pla te f l ari n th r t f uptake f p l o pl u in l ne ti ue

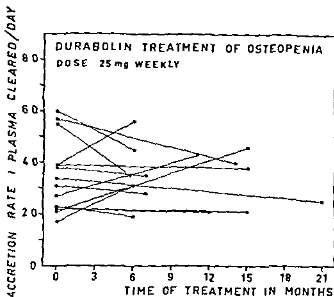


Fig 2
The effect of long term treatment with Durabolin ® on accretion rates *in osteopenic subjects*

cleared per day In the cases of osteopenia associated with rheumatoid diseases and the idiopathic group the mean accretion rates were 3 7 ± 0 35 and 3 4 ± 0 19 liters of plasma cleared per day This decrease which approximates 30 % is significant In the gastrectomized patients with osteopenia the accretion rate did not differ significantly from the normal group the mean value being 5 1 ± 0 37

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Acknowledgement

This investigation was supported in part by a grant from the Swedish Medical Research Council in part by a P S H research grant (D-1652) from the United States Public Health Service

CHEMICAL ANALYSIS AND MICRORADIOGRAPHIC INVESTIGATIONS FROM BONE SPECIMEN FROM CASES OF OSTEOPOROSIS AND NORMALS

by *E Dollerup* and *Hans Bohr* (Aarhus and Copenhagen)

Bone specimen from the iliac crest in 58 cases of idiopatic osteoporosis have been analysed for the content of nitrogen calcium and phosphorus and the results compared with a similar analysis of normal bone from different age groups The dia

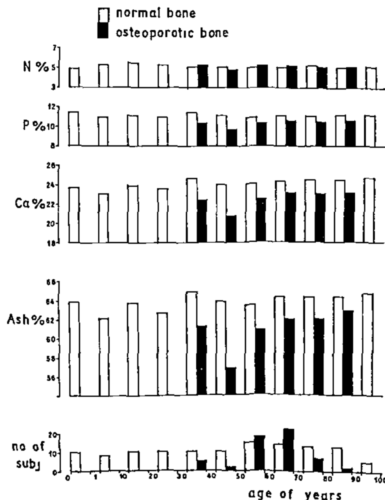


Fig 1

gnosis of idiopatic osteoporosis was made when X-ray photos of the lumbar spine showed the characteristic signs of osteoporosis and other diseases could be excluded at the examination in the Municipal Hospital or the Orthopaedic Hospital of Aarhus. The normal cases were chosen at post mortem examination among cases of fatal accidents or sudden death, when there had not been any prolonged bed rest or any known disease which could have influenced the calcium metabolism of the skeleton.

The bone specimens divided into compact and cancellous bone and by a thorough rinsing in running water the marrow was removed. Fat was further extracted by ether and the bone dried at 100° C. to constant weight. Determinations of nitrogen were made by the method of *Kjeldahl* and determinations of calcium and phosphorus after ashing at 600° C. by the method of *Biedermann & Schwartzenback* and the method of *Fiske & Subbarow* respectively.

A summary of the results for cancellous bone is given in Fig. 1, where the amounts of nitrogen, phosphorus, calcium and ash are given in percentage of dry bone. It is seen that while the nitrogen content is nearly the same in normal and osteoporotic bone, the amount of phosphorus and calcium is definitely lower in osteoporotic bone. Consequently the relation of Ca/N and P/N is below normal in osteoporosis indicating a lesser degree of mineralization.

Microradiographic investigations have showed a normal bone structure in idiopatic osteoporosis. An attempt to evaluate the rate of new building of bone by calculating the number of less mineralized Havershen systems as compared with the fully mineralized Havershen systems failed to show any decisive difference between normals and cases of idiopatic osteoporosis. As this study was only on a semi-quantitative scale it does not contradict the results of the chemical analyses mentioned above.

OSTEOPOROSIS AND MALABSORPTION OF CALCIUM—SUCCESSFUL TREATMENT WITH LARGE DOSES OF VITAMIN D IN A 24 YEAR OLD WOMAN WITH TOO LITTLE CALCIFIED BONE WITHOUT EXCESS OF OSTEOID TISSUE

by *Ole Munck* (Copenhagen)

The patient was a 24 year old woman with symptoms of generalized bone disease during the last six years. X-ray showed fractures of the spine and pronounced decrease of the bone density throughout the skeleton. Lamina dura of the teeth was intact and there were no erosive changes of the phalanges. The serum concentrations of calcium, phosphorus and alkaline phosphatase were normal. Calcium and nitrogen content in bone was normal. Renal function was normal. Corticoidmetabolites and estrogen excretion in urine normal. Fecal fat excretion was *normal in four 4 day* periods: 2.5, 5.5, 7.5 and 5.0 g/hours on a daily intake of 80 g. fat. A biopsy from the iliac crest is shown in Fig. 1.

The left part is an ordinary photo, the right part a microradiograph. The trabeculae are mince, there is no defect in mineralization and there is not an excessive amount of uncalcified osteoid tissue. This sum of observation points unequivocally to the diagnosis osteoporosis.

Fig. 2 shows the calcium balance during 80 4 day period. Food, feces and urine were analysed for calcium, phosphorus and nitrogen *in each period*. The data was charted according to *Albright*, so that positive balance is indicated by white areas under the zeroline. In the [illegible] control periods the average balance was negative with





Fig 1
Micrcradiograph cf bi psv from iliac crest

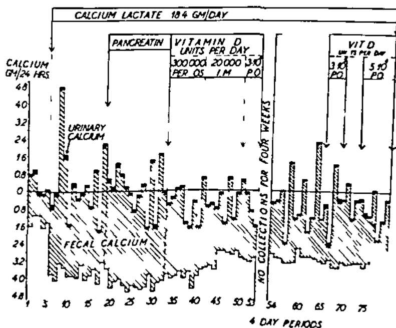


Fig 2
Calcium bal nce during 320 lay

367 mg/24 hrs due to fecal loss An extra supply of 2 4 g calcium per day did not result in positive balance (13 periods) Addition of pancreatic enzymes was also without significant effect (14 periods) Then 300 000 i u of vitamin D was given daily during 12 periods interrupted by 9 periods when 20 000 i u was given daily intramuscularly This treatment resulted in a positive calcium balance on average +572 mg/24 hrs this being a highly significant difference ($p < 0.001$) from the average of —248 mg/24 hrs in all the 32 periods where no vitamin D was given During the last 27 periods the balance remained positive with an average of +574 mg./hrs The total gain of calcium during vitamin D treatment was 110 g X ray showed an increase in bone density

This combination of observations has not been reported previously and may therefore contribute to the questions of etiology and treatment of osteoporosis

Thanks are due to Dr *H Bohr* for performing the microradiograph and to Dr *E Dollerup* for the chemical analyses of bone

CORTICAL OSTEOPOROSIS

by *Olov Lindahl* and *Åke G H Lindgren* (Stockholm)

It is a common concept that there is a reduction of the amount of cortical bone in osteoporosis No systematic investigations seem to have been published regarding this

We have collected one femur and one humerus from each of 64 autopsy cases with an equal distribution between the sexes and with ages between 15 and 90 years The weight the volume and the average outer diameter of these specimens were determined From this data the true density and the average cross section area were calculated We think that the average cross section area gives a good conception of the amount of cortical bone in the body

The average outer diameter of the femur was 33 mm in men and 30 mm in women and of the humerus 26 mm in men and 23 mm in women The diameter showed a slight increase with age

The average density of the femur in men and women was 1 92 and 1 78 and of humerus 1 79 and 1 71 g/ml respectively In men there was a slight increase of the density with age but this was not found in women

The mean of the average cross section areas of the femur in men and women was 4 37 and 3 36 and of the humerus 2 33 and 1 52 sq cm respectively There was a slight decrease of the area with age in men but not in women

The following conclusions seem to be indicated from the collected data The *amount of bone mineral is higher in the femur than in the humerus and* also higher in men than women The density of cortical bone varies as much as 100 per cent The changes of the average cross section areas with age do not correlate with the changes of the apparent density occurring in spongy bone with age (*Lindahl & Lindgren* Acta Orth Scand 32 85 1962)

PROGRAMME DES JOURNEES ORTHOPEDIQUES
DE L HOPITAL *RAYMOND POINCARE* (Garches)

Service du Professeur *Robert Judet*

Le 7 – 8 et 9 Mai 1964

JEUDI 7 MAI 1964

– GENOU

9 h à 13 h – *Interventions*

- Fractures articulaires de l extremite superieure du tibia
- Ostétomies dans les gonarthrosees
- Arthroplastie du genou

15 h à 18 h – *Exposés et discussions*

- Film
- Presentation de malades

VENDREDI 8 MAI 1964

ABORD OSSEUX PAR DECORTICATION OSTEO MUSCULAIRE

9 h à 13 h – *Interventions*

- Pseudarthroses
- Pseudarthroses suppurees
- Cal vicieux
- Osteosynthese secondaire precoce des fractures

15 h à 18 h – *Exposes et discussions*

- Etude experimentale de la question

SAMEDI 9 MAI 1964

– POIGNET

9 h à 13 h – *Int rventions*

- Fractures de l extremite inferieure du radius
- Cals vicieux du poignet
- Fractures et ps udarthroses du scaphoide
- Arthrodese poignet

15 h à 18 h – *Expos s et discussions*

- F lms
- Pr entations de malades

18 h – COCKTAIL DADIEU

L organis n pre oit des matiné s operat ires de 9 h à 13 h des après midi de d m n trati n theorique d pre entations de malades et de projecti ns de films de 15 h à 18 h

La bro l ant les exp sé et les descriptions d s "Journe s de 1961 1962 et 1963 s le au "Secretariat des Journ es" qui prendra également les inscripti n t hure des Journees 1964" (Mass n Editeur)

P ur f n ati n matérielle des Journ s n est prié de s in crire en écri an tre lu Service

Une part 100 Fr era dem n l e p ur les frais de Television et les d jeuner q r nt ur place

La parti J urnee " era g atuite p ur les int rne et les Chefs Clinigu en x ti n de repas (Repas 7 Frs)